CFD Analysis of Wind Microclimate Pedestrian Conditions
Eden Project North, Morecambe

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1. Executive Summary

1.1. Introduction

A new landmark leisure development is proposed for the Seafront Headland, Central Promenade, north of Marine Road Central in the town of Morecambe.

Hilson Moran has been appointed by the developer, Eden Project International Ltd, to provide a quantitative wind microclimate assessment for the proposed development against the widely used Lawson Criteria. The analysis considers two scenarios: Existing, & Proposed, using CFD simulations from 36 wind directions.

1.2. Effects of the Proposed Development

1.2.1. Comfort

As detailed in section 6.1 and Figure 6.2, simulations show that, following the development, the conditions in all regions continue to be milder than the existing conditions, and milder than the required comfort threshold in most locations. Simulations show six regions in which conditions are likely to be not "acceptable" according to the Lawson pedestrian comfort criteria for the intended activities. After accounting for panoramic locations and the proposed landscaping strategy, there are four remaining regions which would require mitigation, in the form of increased soft landscaping.

1.2.2. Distress

As described in section 6.2, simulations show no regions of pedestrian distress for general users within the assessment area for either the existing or proposed scenarios.

As detailed in section 6.2 and Figure 6.4, simulations show that, following the development, no new regions of distress for frail pedestrians and cyclists are introduced offsite within the assessment area, although some large off-site regions still remain, including the locations of two pedestrian crossings on Marine Road Central. Lancaster City Council may wish to consider providing additional local shelter for these crossings.

Simulations show three on-site regions of distress for frail pedestrians and cyclists. After accounting for alternative routes and the proposed soft landscaping, there are two remaining on-site regions which would require mitigation, in the form of increased soft landscaping.

1.2.3. Mitigation

Section 6.4 provides details of locations where additional local shelter through soft landscaping would provide improved wind microclimate conditions for each region where mitigation would be required. A site-wide summary of these locations is indicated in Figure 7.1.

Table 1.1: Summary of Mitigation Requirement Locations

ID	Location	Criteria
a)	Two seating regions overlooking the seafront	Pedestrian Comfort
b)	Two seating regions in the southwest of the site	Pedestrian Comfort
c)	At the southeast corner of the main building	Pedestrian Distress for Frail People or Cyclists
d)	At the southeast corner of the site	Pedestrian Distress for Frail People or Cyclists

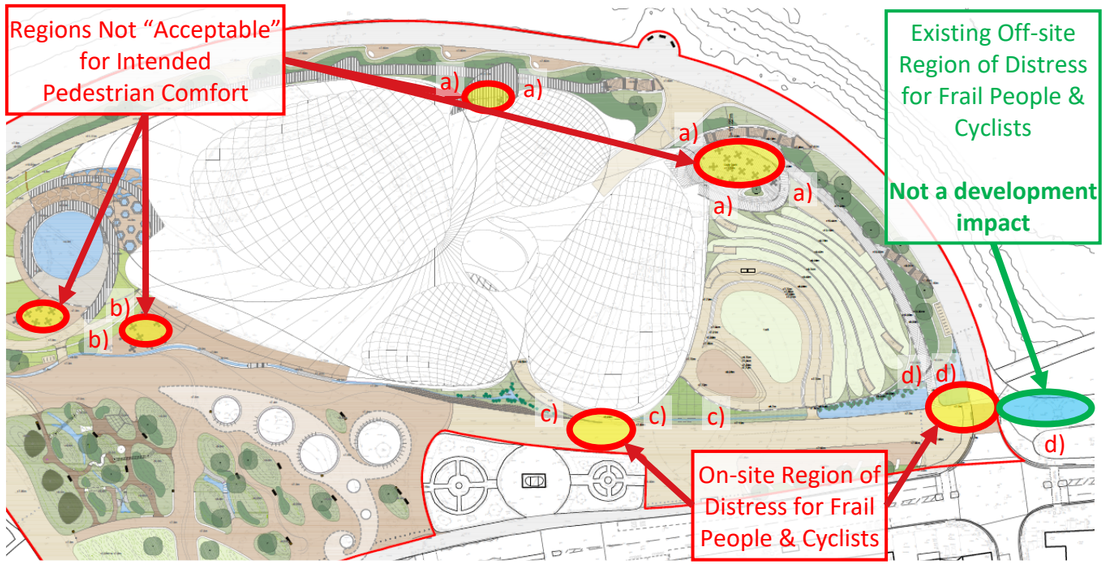


Figure 1.1: Summary of Suggested Locations for Mitigation Requirements a), b), c), & d)

1.3. Conclusions

Simulations show that the impact of the proposed massing is likely to be **beneficial** to the off-site pedestrian wind microclimate for both comfort and distress. After accounting for other effects, including panoramic location, alternative routes, and the proposed landscaping strategy:

- Four locations are unlikely to achieve the required **comfort** conditions;
- Two locations are unlikely to achieve the required **distress** conditions for frail people and cyclists;
- Some significant existing off-site regions of distress for frail people and cyclists will remain, including the locations of two pedestrian crossings on Marine Road Central.

Additional local shelter through soft landscaping would provide improved wind microclimate conditions for each region where mitigation would be required, as summarised in Figure 7.1.

2. Introduction

2.1. Outline of the Proposed Development

A new landmark leisure development is proposed for the Seafront Headland, Central Promenade, north of Marine Road Central in the town of Morecambe.

Hilson Moran has been appointed by the developer, Eden Project International Ltd, to provide a wind microclimate assessment for the proposed development. The objective of this study is to provide a ground level wind microclimate assessment based on a series of computational models.

2.2. Existing Built Environment

The main development site bound by the promenade to the north and east, Marine Road Central to the south and the Grade II* listed Midland Hotel to the west.

Figure 2.1 shows an image of the existing site. The site comprises vacant land, public gardens, car parking space and outdoor auditorium seating. The site currently includes a handful of large shrubs, and three trees at the western end of the site, near the Midland Hotel.

The existing surrounding building stock is typically 2-4 storeys high. The Midland Hotel to the west is ~16m high. The Grade II* listed Winter Gardens building to the southeast of the site rises from ~16m high at the front to ~23m high at the rear.

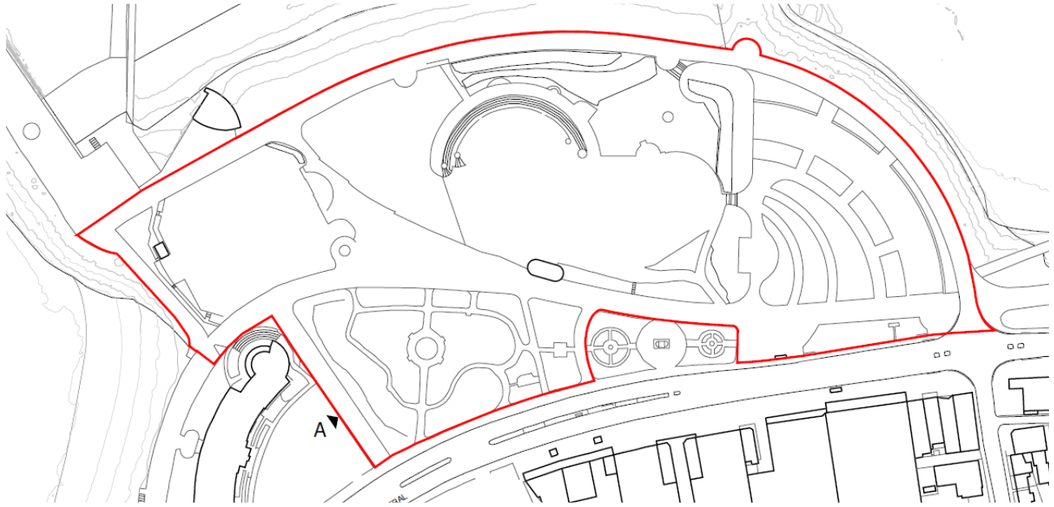


Figure 2.1: Existing Site

2.3. Proposed Development

As shown in Figure 2.2, the proposed development comprises 4 main domed halls, of between 16-30m in height. A surrounding lower section rises up to 12m with an open central plaza. An eastern landscaped area rises to 6m, while a western outdoor sunken garden falls to ~3m below the surrounding ground level.

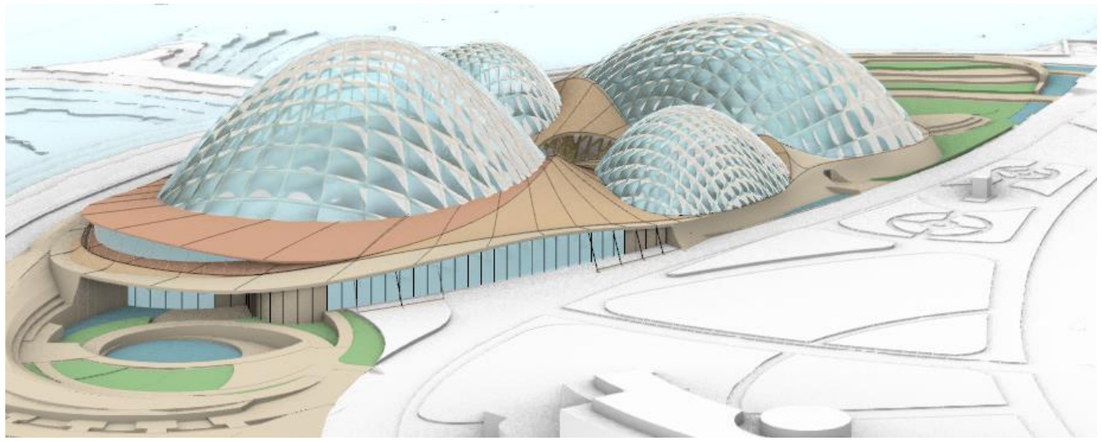


Figure 2.2: Proposed Massing

2.4. Purpose and Scope of the CFD Study

The purpose of this report is to assess the acceptability of wind conditions as a result of the proposed development. This analysis considers two scenarios: Existing & Proposed. There are no cumulative developments to assess.

The investigation was performed using a CFD model constructed using the general purpose ANSYS-Fluent CFD package. The models enable a quantitative analysis of flow characteristics in the microclimate around the buildings. Simulations were performed from 36 wind directions in 10° increments around the compass.

This report summarises the models constructed, the simulation methodology, main assumptions made and the boundary conditions applied. The results of the CFD simulations were interrogated to compare the proposed uses with metrics of user comfort criteria.

Wind conditions were quantitatively assessed against the widely used Lawson Criteria, as set out in Building Aerodynamics by Tom Lawson, [Imperial College Press (2001)].

The CFD results were analysed including a brief discussion of possible causes of undesirable flow features and possible measures to counteract these. This report includes appropriate conclusions and recommendations.

2.5. Limitations of Modelling

2.5.1. Suitability for Purpose

The analysis reported in this document uses CFD models to simulate the likely wind speeds under a variety of wind conditions, for comparison against the LDDC Lawson comfort criteria. CFD is widely used for this purpose, and more importantly is well-validated against both empirical data and other modelling methods.

Irrespective of modelling methodology, the results of modelling physical phenomena have uncertainty compared with the real life performance. All modelling techniques fail to predict reality with perfect precision, due to necessary assumptions, unpredictable boundary conditions or other simplifications. It is therefore important to address the purpose for which the modelling was undertaken.

This assessment considers wind pedestrian comfort and distress for general patterns of use (i.e. sitting, standing, strolling, and walking). The following effects were not considered in this analysis:

- More specialised wind design requirements (e.g. sailing, aviation, sports, particle transport, fire safety, etc.)
- Structural effects, resonance calculations, fluid-structure interactions, and acoustic effects;
- Ventilation of internal spaces, wind gusting, urban heat island effects and pollutant tracking;
- Wind effects during construction.

3. Legislation and Planning Policy

Legislation and planning documents of relevance to this assessment include the following:

- The National Planning Policy Framework (July 2021);
- Planning Practice Guidance (2014)

National planning policies do not impose specific limits on the microclimate wind environment around a new development, but there is a requirement to inform the planning process, so that specific site conditions and functions can be assessed, and to show that other users around the development will not be unreasonably affected by the wind microclimate.

As a result it is proposed to assess effects based on UK industry standards, assessing the pedestrian level wind microclimate against the Lawson pedestrian comfort criteria. The Lawson criteria define acceptable windiness for different activities such as sitting, walking and standing.

3.1. Legislation

There is no legislation which specifically governs wind microclimate planning policy.

3.2. National Planning Policy

3.2.1. National Planning Policy Framework (July 2021)

The National Planning Policy Framework (NPPF) does not specifically reference wind or microclimate; however, the NPPF emphasises the benefits of high quality built environment, for example:

Paragraph 90.b)	*"This should include assessment of [...] the impact of the proposal on town centre vitality and viability."*
Paragraph 126	*"Good design […] creates better places in which to live and work and helps make development acceptable to communities."*
Paragraph 130.f)	*"Planning policies and decisions should ensure that developments create places that are safe, inclusive and accessible [...] with a high standard of amenity for existing and future users."*

3.2.2. Planning Practice Guidance (2014)

Planning Practice Guidance identifies the potential for a development's size and shape to affect the wind microclimate. In particular, paragraphs 25 and 26 state:

"*Design: How should buildings and the spaces between them be considered?*

Consider Form: Some forms pose specific design challenges, for example how taller buildings meet the ground and how they affect local wind … patterns should be carefully considered.

Consider Scale: Account should be taken of local climatic conditions, including … wind".

3.3. Local Planning Policy

A review of the relevant policies for Lancaster City Council did not highlight any specific wind microclimate requirement additional to the regional and national planning policies.

4. Inputs

4.1. Geometry

The geometry of the proposed development in the CFD model was based on a 3D pdf provided by Grimshaw Architects, including existing neighbouring buildings. In addition, publicly available LiDAR data for the wider region was used in constructing the model, including the existing site.

4.2. Location

Figure 4.1, shows an overview of the model geometry. The location of the proposed development is highlighted. The model domain extends to a radius of more than 5 times the proposed building height.

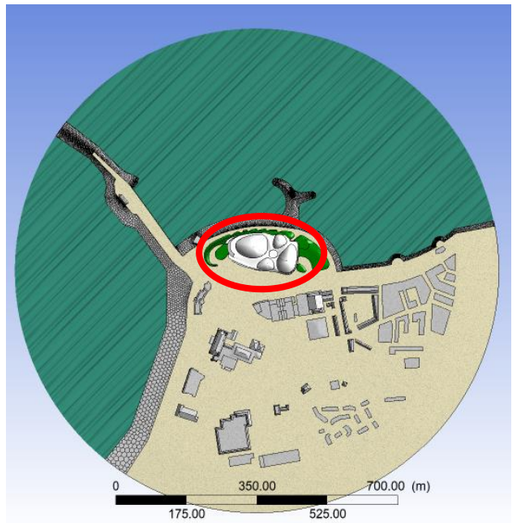


Figure 4.1: Overview of model geometry, and highlighted location of the development



Figure 4.2: Example of typical proposed soft landscaping and local shelter.

4.3. Vegetation

The proposed landscaping strategy includes provision of trees, soft landscaping, and local shelter. These are shown in Appendix A – EDNN-TEP-ZZ-ZZ-DR-LA-001-Landscape General Arrangement_DRAFT_10.08.21 (002).pdf. The details of the proposed soft landscaping will be determined after the planning submission.

It is extremely difficult to precisely quantify the effect of an individual tree on airflow. The porosity and resistance to flow is highly sensitive to many factors such as species, age, health, aspect, soil, season, etc. In addition, the highest wind speeds experienced in the United Kingdom tend to occur during winter, when deciduous trees are leafless.

Although the presence of a particular tree might conceivably cause an acceleration of flow in one localised region under a specific scenario, its overall effect on the pedestrian environment will be to reduce the average velocity experienced. As a result, vegetation has not been included in the simulations. The omission of individual trees from the models may be considered to be an appropriate conservative measure.

The effect of vegetation has instead been accounted for in a subsequent experience-based qualitative update to the simulation results.

4.4. Raw Wind Data

This assessment uses 30 years of wind data measured at the weather station at Walney Island, approximately 26km to the westnorthwest of the proposed development. This is considered to be the most representative long term dataset for the site. The resulting wind rose in Figure 4.3, indicates that the prevailing wind direction is from the west quadrant (220°-300°) with secondary winds from the east.

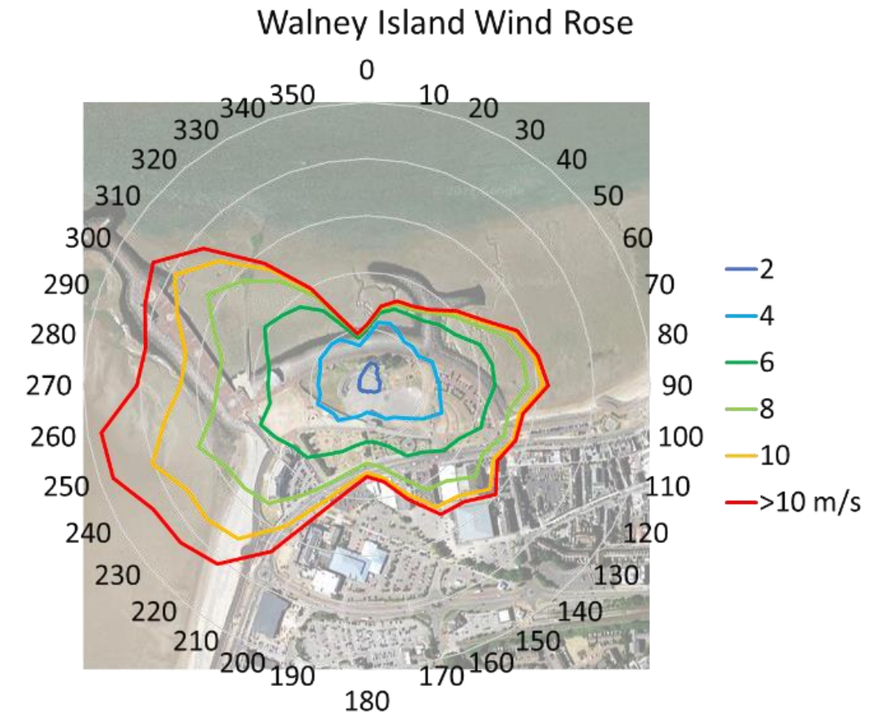


Figure 4.3: Wind Rose for Walney Island

4.5. Surface Roughness

Average wind speed increases with distance from the ground and this, along with turbulence effects has a significant impact on the resulting wind profiles around the buildings.

The roughness of the upwind ground surface is important in the formulation of the wind boundary layer. It affects the variation in atmospheric boundary layer, thus affecting the wind velocity felt at pedestrian level on the site.

The wind data from the measurement location has been adapted for the site, producing incoming wind profiles, calculated for 12 wind directions using the latest industry standard ESDU 01008 methodology. Since simulations are undertaken for 36 wind directions, each wind profile was used for 3 simulations.

Table 4.1 indicates the roughnesses appropriate for various terrains surrounding the proposed development.

Table 4.1: Terrain Categories

Description	z_0 (m)
Centres of large towns and cities:	0.7
Centres of small towns:	0.5
Suburbs, villages:	0.3
Parks, hedges, some trees:	0.08
Open Country, Airport runways	0.03

5. Methodology

To identify the likely effect of the proposed development on the pedestrian level wind environment, 3D CFD models of the proposed development and surrounding site were created. This section describes the methodology for the creation of this model and the inputs used.

5.1. Computational Fluid Dynamics

Simulations of the microclimate were conducted using ANSYS-Fluent CFD software.

The computational process involves the solution of fundamental equations of fluid motion within the CFD software. A computational mesh was created to represent the geometry by dividing the domain into a large number of cell volumes. During the simulation, the values of each variable are determined in each cell of the mesh and so a comprehensive assessment of velocity and scalar variation within the calculation domain is obtained. The dependent variables are as follows:

- Velocities in the three co-ordinate directions (U, V, W)
- Pressure (P)
- Turbulence Kinetic Energy (k)
- Turbulence Dissipation Rate (ε)

Steady-state simulations were conducted to convergence for 36 wind directions for each geometrical model, using the realisable k-ε turbulence model. The coupled, pseudo-transient solver was used with second order discretization for all variables, including pressure.

5.2. Geometry

CFD simulation of likely wind patterns requires the generation of a 3D computer model of the site and surrounding buildings.

The data listed in section 4.1 was used to construct a model of the buildings and surrounding area. Figures 5.1 to 5.2 show the modelled geometry.

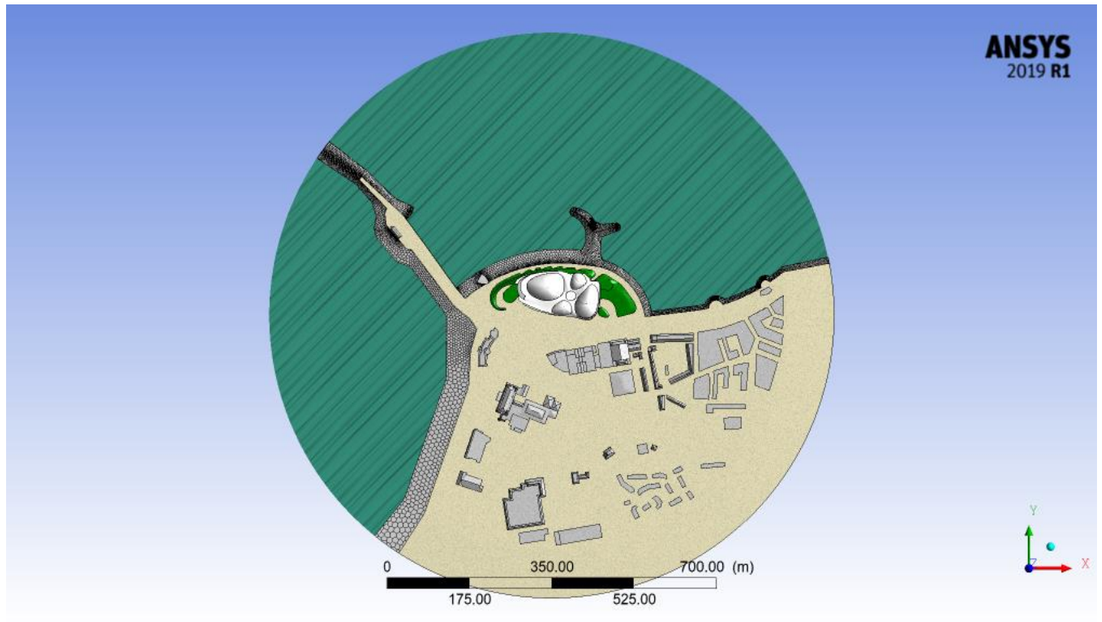


Figure 5.1: Simulated Geometry: Plan View

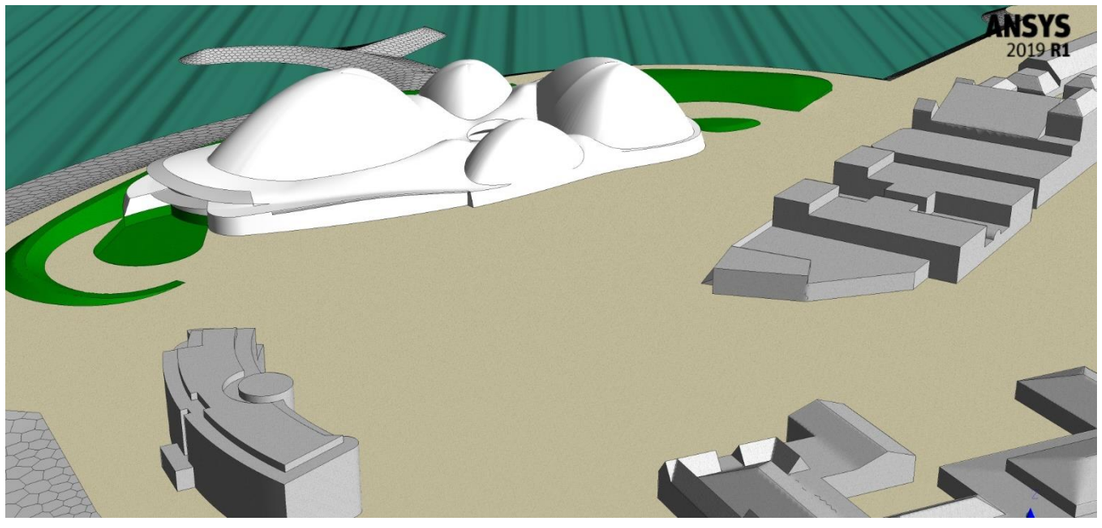


Figure 5.2: Simulated Geometry: Isometric View of Proposed Development

5.3. Mesh

To improve the resolution of the results, the mesh was concentrated in the areas of most interest (at pedestrian level around the Proposed Development) and around significant small-scale flow features. This ensures greater accuracy of the variables under investigation. Layers of thin prisms were applied to all solid boundaries, to improve resolution of boundary layers at these locations. The models used approximately 3 million elements.

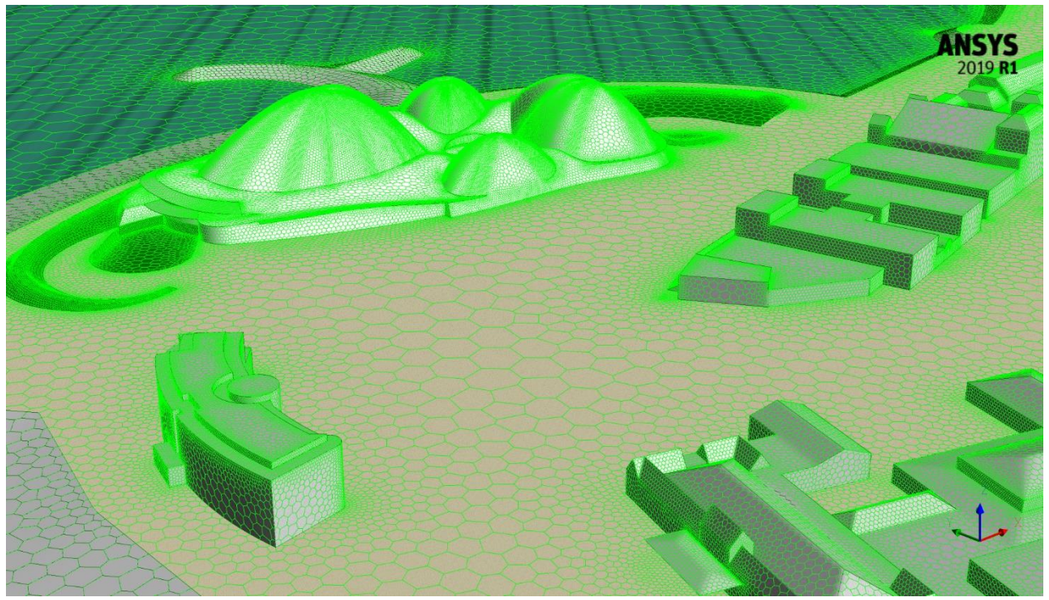


Figure 5.3: CFD Surface Mesh of Proposed Site with Adjacent Buildings

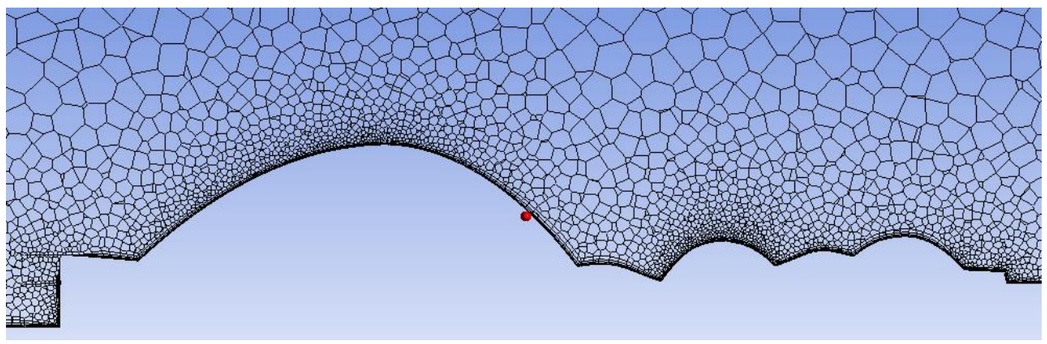


Figure 5.4: Vertical section through CFD Volume Mesh, showing Polyhedra, and Prisms.

5.4. Boundary Conditions

A cylindrical computational domain was used for the analysis. This allows the wind direction to be altered without changing the computational mesh. Around the perimeter of the domain, a profile for the velocity and turbulence parameters was specified to take into account how the wind speed changes with the height from the ground. Surfaces within the model were specified as having 'no slip'. This condition ensures that flow moving parallel to a surface is brought to rest at the point where it meets the surface.

Accurate specification of the boundary layer wind profile is crucial in correctly simulating the pedestrian level wind environment. The wind data from the measurement location has been adapted for the site, producing incoming wind profiles, calculated for 12 wind directions using the latest industry standard ESDU 01008 methodology. Since simulations are undertaken for 36 wind directions, each wind profile was used for 3 simulations. The simulated wind speeds corresponded to the highest decile of measured wind speeds, and is representative of typical strong winds.

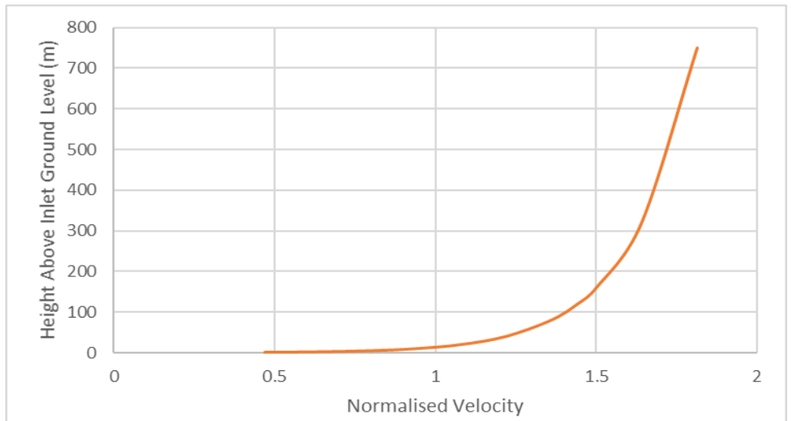


Figure 5.5: Typical Vertical Profile of Inlet Velocity

5.5. Lawson Criteria

This report compares simulated results against the widely used LDDC Lawson Criteria, as set out in Building Aerodynamics by Tom Lawson, [Imperial College Press (2001)].

To produce the Lawson plots shown in section 6.1, statistical analysis of the number of hours and magnitudes of wind for 36 angles (10° increments) around the compass is performed. Results from each of the 36 simulated wind directions were measured at 1.5m above pedestrian level. From these measurements, the "speed-up" factors for each wind direction are combined with the wind frequency statistics for each direction to estimate the probability that the wind speed exceeds each threshold. This was performed at each point on the site, according to the wind data shown in Figure 4.3.

5.5.1. Comfort Criteria

Public sensitivity to wind is dependent on activity. Someone sitting to eat outside a café will be more sensitive than someone hurrying to work/home.

For reporting the Lawson comfort criteria, this report uses the colour scale shown in Table 5.1. Regions coloured according to a given category are considered “acceptable” for the corresponding activity and all those with faster thresholds. E.g., if an area is coloured with the green shown for ‘category III’ then it will be acceptable for pedestrian walking and business walking but not acceptable for pedestrian standing and pedestrian sitting.

The Lawson comfort criteria take full account of reduced use during windier times of the year. They are based on a user’s typical expectations, given the general weather conditions.

Table 5.1: LDDC Lawson Comfort Criteria Definitions

	Lawson Comfort Category	Threshold Wind Speed	Threshold Description	Threshold Condition	Activity
	Pedestrian sitting	95 %ile < 4m/s	Light Breeze	Wind felt on face; leaves rustle; wind vane moved by wind	Long term sitting (e.g. outdoor cafes/bars)
	Pedestrian standing	95 %ile > 4m/s	Gentle Breeze	Leaves and small twigs in constant motion; light flags extended	Standing and main entrances (benches, bus-stops, markets, playgrounds etc.)
	Pedestrian walking	95 %ile > 6m/s	Moderate Breeze	Raises dust and loose paper; small branches moved	Leisure walking (shops, canals, parks, etc.)
	Business walking	95 %ile > 8m/s	Fresh Breeze	Small trees in leaf begin to sway; crested wavelets form on inland waters	People busy getting from A to B
	Roads & Car Parks	95 %ile > 10m/s	Strong Breeze	Large branches in motion; whistling heard in telegraph wires; umbrellas used with difficulty	Roads and Car Parks

5.5.2. Distress Criteria

The distress criteria assessment also uses the LDDC Lawson method, as set out in Building Aerodynamics, [Imperial College Press (2001)]. These state that for elderly or infirm pedestrians, the hourly mean wind speed should exceed 15 m/s for less than 0.025% of the year (approximately 2 hours). For able-bodied pedestrians, the hourly mean wind speed limit should exceed 20 m/s for less than 0.025% of the year. Should these be exceeded for more than 0.025% of the year, the method informs the wind engineer to consider if “the location [is] on a major route through the complex, and are there suitable alternate routes which are not ‘distressful’.

For reference, the 20m/s criteria is approximately the same as the Beaufort category for strong/severe gale (Slight structural damage - chimney pots and slates removed).

Although these criteria are formally titled “Pedestrian Distress”, they are commonly used as the basis of discussion for Pedestrian Safety, and have been adopted as such by some councils.

6. Results

6.1. Pedestrian Comfort

6.1.1. Existing

Figure 6.1 shows that most areas are likely to be currently acceptable according to the Lawson Comfort Criteria for the existing activities. The seafront is a panoramic location, and therefore still considered acceptable for Category III (Pedestrian Walking). Although there are several benches provided along the seafront, these are likely to be for the benefit of those who are intentionally seeking exposed seafront conditions.

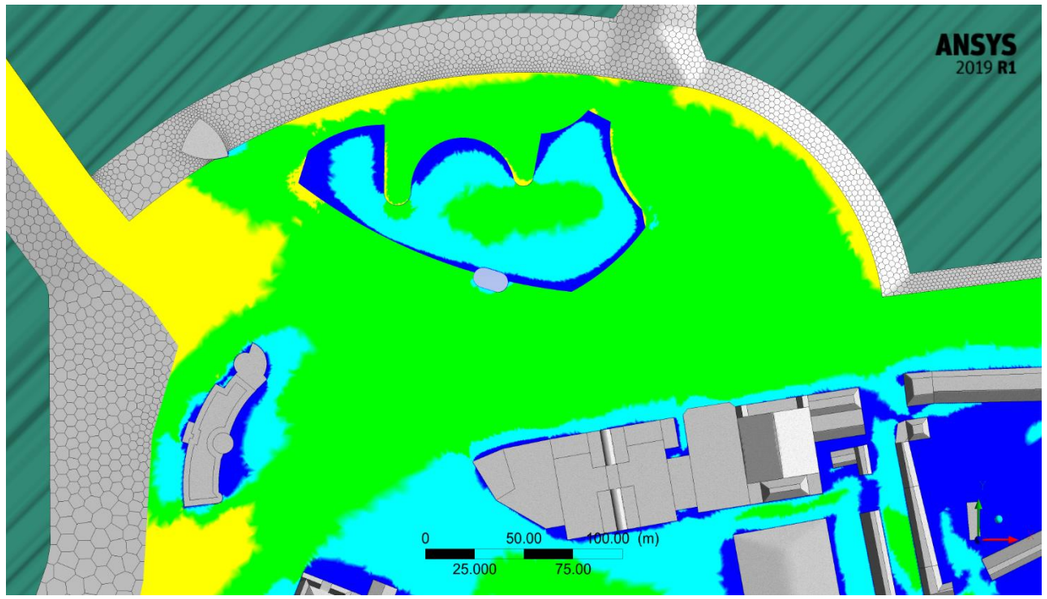


Figure 6.1: Lawson Comfort Plot – Existing

Table 6.1: LDDC Lawson Comfort Criteria Typical Activities

	Comfort category	Colour	Location examples
I	Pedestrian sitting		Cafés, Outdoor Auditoria
II	Pedestrian standing		Bus stops, Main entrances, Playgrounds, Park Benches, Markets
III	Pedestrian walking		Retail Areas, Parks, Canals
IV	Business walking		"Busy" getting from A-to-B (i.e. not necessarily financial)
	Roads and Car Parks		Roads and Car Parks

6.1.2. Proposed

Figure 6.2 shows that, following the development, in all regions, the conditions continue to be milder than the existing conditions, and milder than the required threshold in most locations. The simulations show that wind conditions do not deteriorate away from the site of the proposed development.

There are six on-site regions in which simulated conditions are shown to breach the Lawson Comfort Criteria for the intended activities. These are listed below, and correspondingly labelled in Figure 6.2. Additional effects to be considered are discussed in section 6.3. Mitigation of these regions is discussed in section 6.4.

i) The brows of the raised landscaped regions are shown as Category IV (Business Walking)
ii) The entrance to the development in the middle of the south façade is shown as Category III (Pedestrian Walking).
iii) Two seating regions overlooking the seafront are shown as Category III (Business Walking).
iv) Two seating regions in the southwest of the site are shown as Category III (Business Walking).

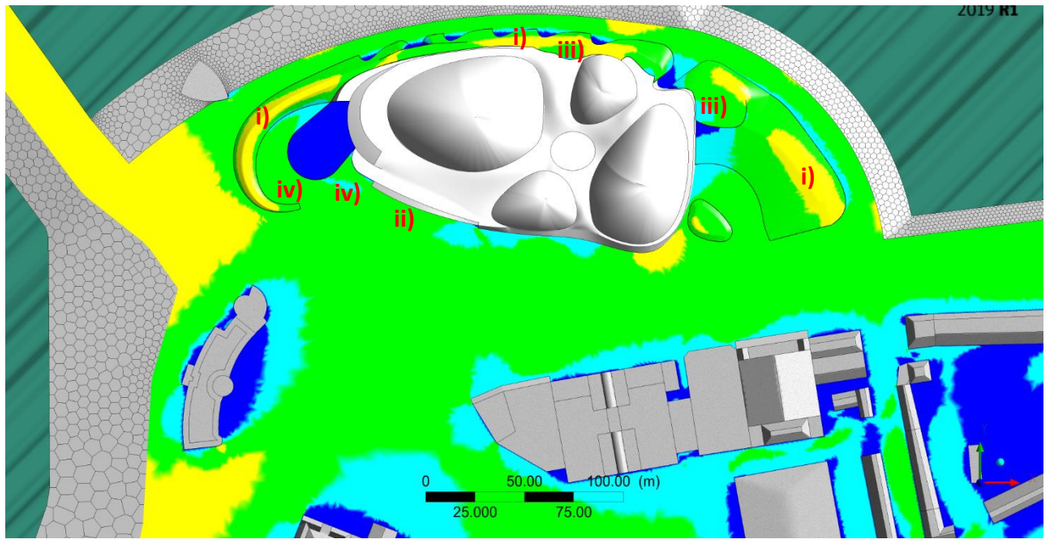


Figure 6.2: Lawson Comfort Plot - Proposed

6.2. Pedestrian Distress

6.2.1. General Users

Simulations show **no regions** of pedestrian distress for **general users** within the assessment area for either the **existing or proposed** scenarios.

6.2.2. Existing - Frail People & Cyclists

Figure 6.3 shows large existing regions of distress (highlighted in magenta) for frail pedestrians and cyclists around the site, and along the seafront. As discussed in section 4.3, these simulations do not include the effects of vegetation, which would provide some local mitigation.

All three pedestrian crossings of Marine Road Central in this area lie within these existing regions of distress for frail people and cyclists.

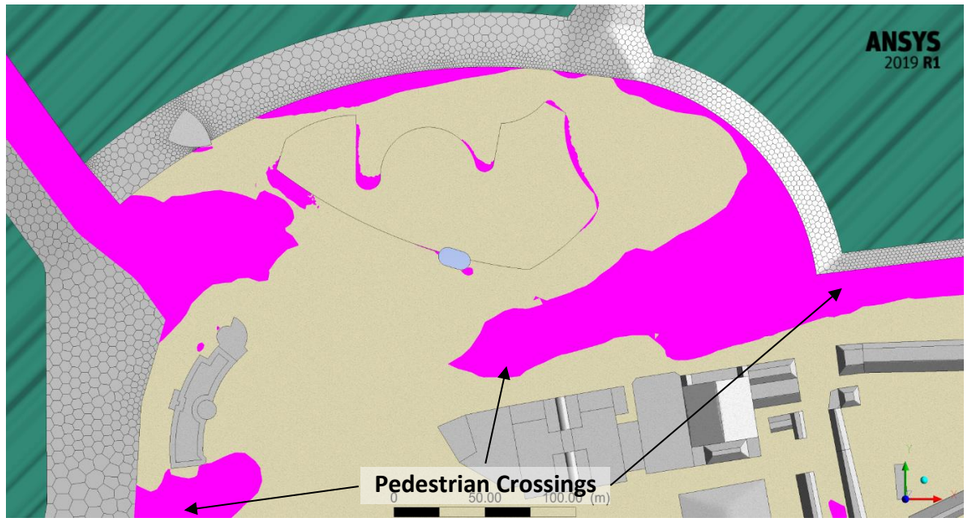


Figure 6.3: Lawson Distress Plot – Existing (Frail People & Cyclists)

6.2.3. Proposed - Frail People & Cyclists

Figure 6.4 shows regions of distress (highlighted in magenta) for frail pedestrians and cyclists.

Simulations show that the proposed development significantly reduces these regions within the assessment area, although some large off-site regions still remain, particularly on the Jetty, south of the Midland Hotel, and the seafront to the east of the site. No new regions of distress for frail pedestrians and cyclists are introduced offsite within the assessment area.

Simulations show three on-site regions of distress for frail pedestrians and cyclists. These are listed below, and correspondingly labelled in Figure 6.4. Additional effects to be considered are discussed in section 6.3. Mitigation of these regions is discussed in section 6.4.

1) The brows of the raised landscaped regions;
2) At the southeast corner of the main building;
3) At the southeast corner of the site.

Of the three pedestrian crossings referred to in section 6.2.2, the proposed development is shown to improve conditions for one of these crossings. Following identification of these regions of pedestrian distress for frail people and cyclists, Lancaster City Council may wish to consider providing additional local shelter for the other two crossings.

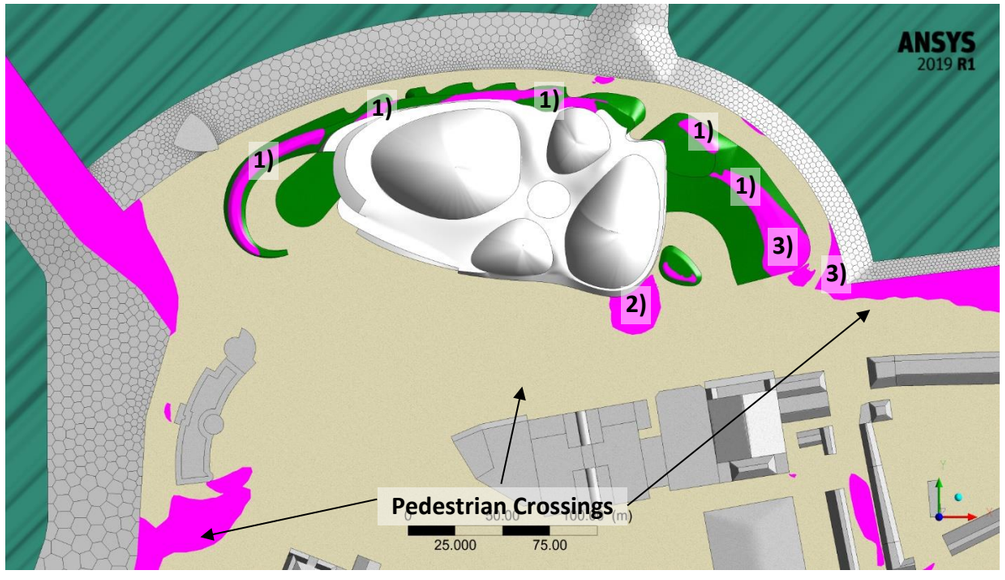


Figure 6.4: Lawson Distress Plot – Proposed (Frail People & Cyclists)

6.3. Additional Effects

6.3.1. Panoramic Location

Panoramic locations are more tolerant of windier environments, as evidenced by outdoor café seating on many seaside piers. Such locations may reasonably be assessed against a comfort category that is one higher than its intended use.

The brows of the raised landscaped regions are shown in Figure 6.2 as Category IV (Business Walking). Given their panoramic location, overlooking Morecambe Bay, they are therefore considered acceptable for Category III (Pedestrian Walking).

The café seating regions overlooking the seafront are both shown in Figure 6.2 as Category III (Pedestrian Walking). Long-term seating is considered Category I (Pedestrian Sitting). Given their panoramic location, overlooking Morecambe Bay, this long-term seating requires conditions which would be acceptable for Category II (Pedestrian Standing).

6.3.2. Minor & Alternative Routes

Assessment of pedestrian distress considers whether "*the location [is] on a major route through the complex, and are there suitable alternate routes which are not 'distressful'.*".

The brows of the raised landscaped regions are shown in Figure 6.4 as having conditions of distress for frail people and cyclists. These regions are not on a major route and alternative routes are available.

6.3.3. Local Shelter & Landscaping

The proposed landscaping strategy includes provision of trees, soft landscaping, and local shelter. These are shown in Appendix A – EDNN-TEP-ZZ-ZZ-DR-LA-001-Landscape General Arrangement_DRAFT_10.08.21 (002).pdf. The details of the proposed soft landscaping will be further developed following the planning submission.

As discussed in section 4.3, soft landscaping is excluded from the quantitative modelling as a conservative measure. This section considers the likely effect of the proposed landscaping strategy.

6.3.3.1. Pedestrian Comfort Location ii) "Entrance to the development in the middle of the south façade"

Figure 6.5 shows 3 trees between 30m and 50m west of the entrance. Two seating areas are shown nearby. Other trees and bushes are shown 30m to the south and beyond, with 5m high porous structures ("energy pods") to the south and east. These landscaping features are likely to produce conditions which are classified as "acceptable" under the Lawson pedestrian comfort criteria.

6.3.3.2. Pedestrian Comfort Location iii) "Two seating regions overlooking the seafront"

As discussed in section 6.3.1, the café seating regions overlooking the seafront require conditions which would be acceptable for Category II (Pedestrian Standing). Figure 6.6 shows a single small tree within the eastern café deck, and other small trees at ~15m-30m distance. "Balustrade/Railings" are also shown at the outer edge of the seating regions. It is assumed that the balustrade here will be solid.

It is uncertain whether the effect of the trees and a solid balustrade would produce conditions which are classified as "acceptable" under the Lawson pedestrian comfort criteria. A minor increase in shelter in these regions may be desired.

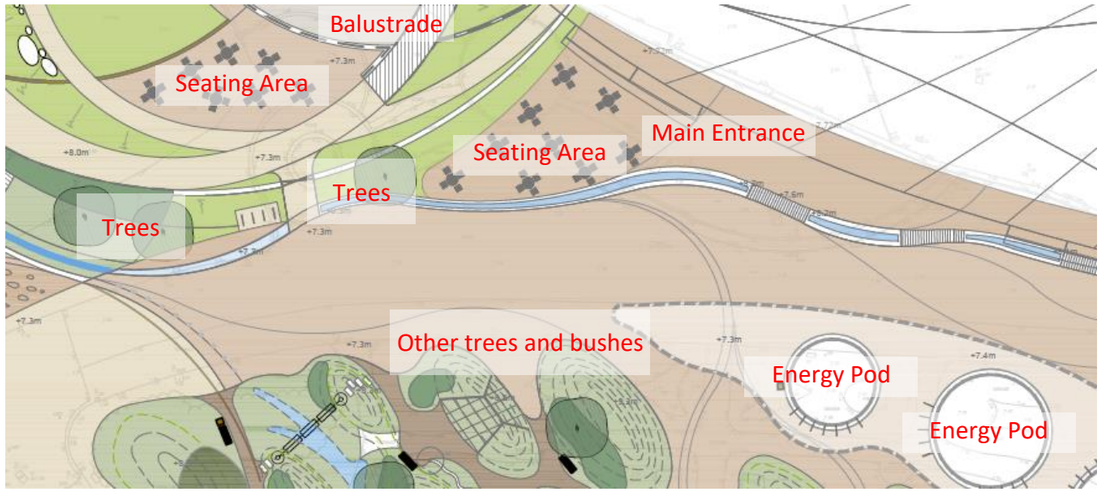


Figure 6.5: Landscaping Near "Pedestrian Comfort Location ii)"

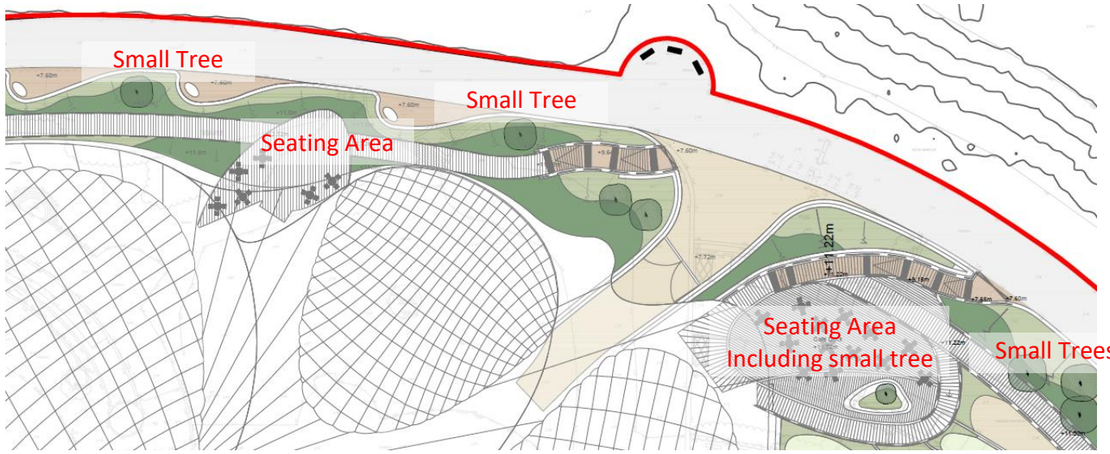


Figure 6.6: Landscaping Near "Pedestrian Comfort Location iii)"

6.3.3.3. Pedestrian Comfort Location iv) "Two seating regions in the southwest of the site"

Figure 6.7 shows 3 trees immediately to the south and west of the seating areas. Other trees and bushes are shown 30m to the south and beyond, with 5m high porous structures ("energy pods") to the south and east. There is a balustrade to the north, and various regions of ground-level mixed coastal planting around the seating areas. It is assumed that the balustrade in this region will be solid.

These landscaping features are likely to improve conditions from Comfort Category III (Pedestrian Walking) to Category II (Pedestrian Standing).

If these seats are intended for long-term sitting, (e.g. café seating), it is likely that these conditions would **not** be classified as "acceptable" under the Lawson pedestrian comfort criteria.

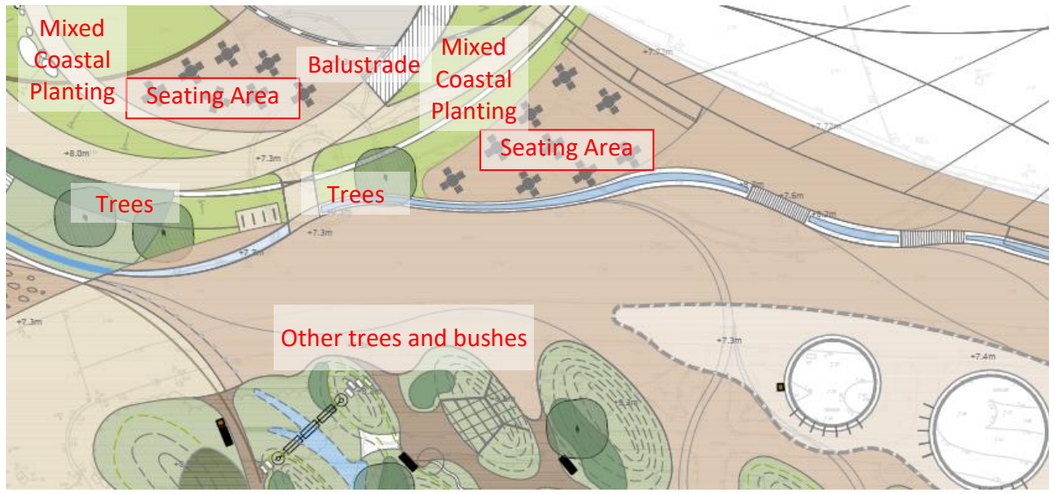


Figure 6.7: Landscaping Near "Pedestrian Comfort Location iv)"

6.3.3.4. Pedestrian Distress Location 2) "At the southeast corner of the main building"

Figure 6.8 shows landscaped public gardens with hedges to the west of the identified region, with trees and 5m high porous structures ("energy pods") beyond. More trees are shown to the southeast. These landscaping features are likely to reduce the region of distress, however there may still be a significant region on the main route, close to the building itself.

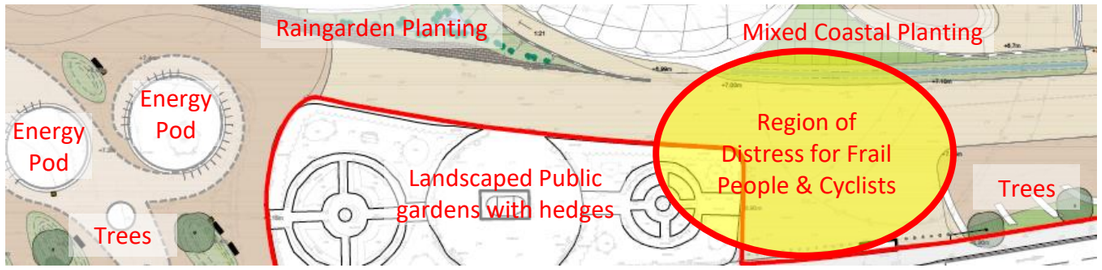


Figure 6.8: Landscaping Near "Pedestrian Distress Location 2)"

6.3.3.5. Pedestrian Distress Location 3) "At the southeast corner of the site"

Figure 6.9 shows 4 smaller trees to the southwest of the identified region, with more trees to the north. Balustrades run along the edge of the water, including the sides of the pedestrian bridge. Considering the prevailing winds from the east and west, these landscaping features are likely to reduce the region of distress in the north, although there is still likely to be a region on the main east-west route at the south end of the bridge.

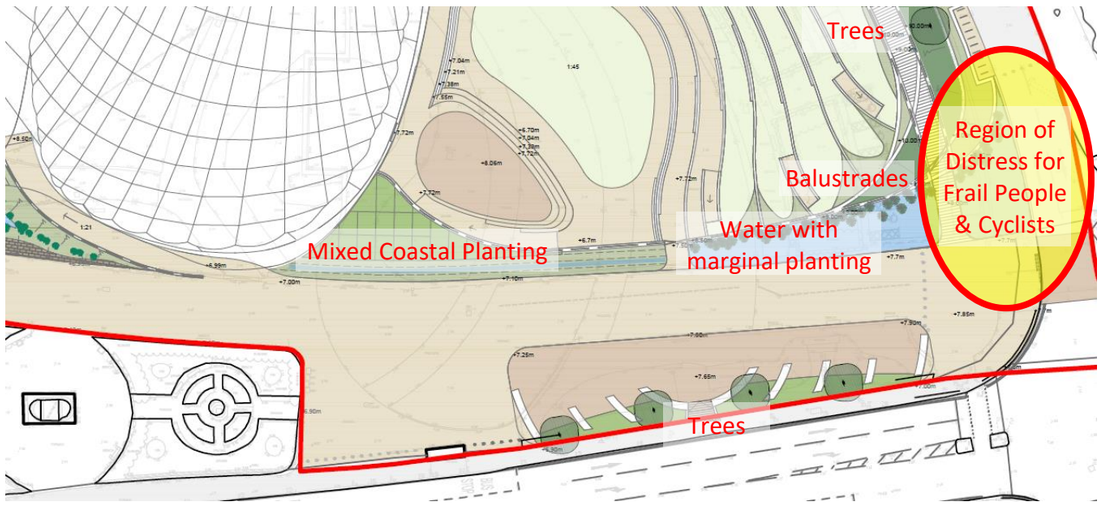


Figure 6.9: Landscaping Near "Pedestrian Distress Location 3)"

6.4. Mitigation

Table 6.2, Table 6.3, and Table 6.4 summarise whether mitigation is required in addition to the current proposed development and its landscaping strategy.

Table 6.2: Summary of Pedestrian Comfort Mitigation Requirement

ID	Location	Required Category	Simulated Category (No Landscaping)	Proposed Landscaped Category	Mitigation Required
i)	The brows of the raised landscaped regions	IV	IV	IV	No
ii)	The entrance to the development in the middle of the south façade	II	III	II	No
iii)	Two seating regions overlooking the seafront	II	III	III	**Yes**
iv)	Two seating regions in the southwest of the site	I	III	II	**Yes**

Table 6.3: Summary of Pedestrian Distress Mitigation Requirement

ID	Location	Simulated Distress (No Landscaping)	Proposed Landscaped Distress	Mitigation Required
1)	The brows of the raised landscaped regions	No Distress	No Distress	No
2)	At the southeast corner of the main building	Frail & Cyclists	Frail & Cyclists	**Yes**
3)	At the southeast corner of the site	Frail & Cyclists	Frail & Cyclists	**Yes**

Table 6.4: Summary of Mitigation Requirement Locations

ID	Location	Criteria
a)	Two seating regions overlooking the seafront	Pedestrian Comfort
b)	Two seating regions in the southwest of the site	Pedestrian Comfort
c)	At the southeast corner of the main building	Pedestrian Distress for Frail People or Cyclists
d)	At the southeast corner of the site	Pedestrian Distress for Frail People or Cyclists

6.4.1.1. Mitigation Location a)

Mitigation may be required at Pedestrian Comfort Location iii) “Two seating regions overlooking the seafront”.

Additional shelter from the prevailing easterly and westerly winds should be directly adjacent to the two seating areas, (e.g. provision of trees or significant shrubs within the adjacent shrub areas).



Figure 6.10: Suggested Locations for Mitigation a)

6.4.1.2. Mitigation Location b)

If these seats at Pedestrian Comfort Location iv) “Two seating regions in the southwest of the site” are intended for long-term sitting, (e.g. café seating), then mitigation is likely to be required.

Additional shelter from the prevailing easterly and westerly winds should be directly adjacent to the two seating areas, (e.g. an upgrade to the region of ground level Mixed Coastal Planting between them, to provide a higher form of soft landscaping).

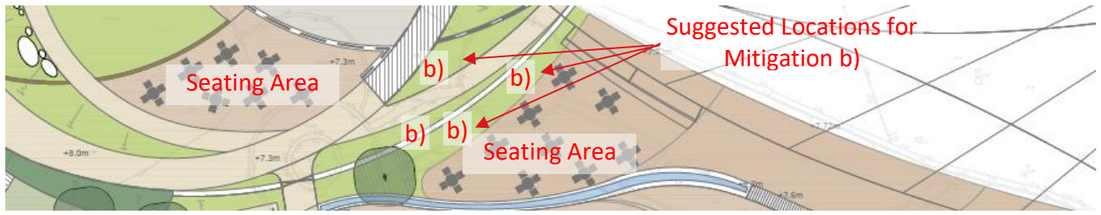


Figure 6.11: Suggested Locations for Mitigation b)

6.4.1.3. Mitigation Location c)

Mitigation is likely to be required at Pedestrian Distress Location 2) “At the southeast corner of the main building”.

It is not straightforward to provide local shelter from east-west winds to an east-west route without obstructing the pedestrian flow. Trees (or other high-level porous structures) should be provided close to the northern edge of the footpath.

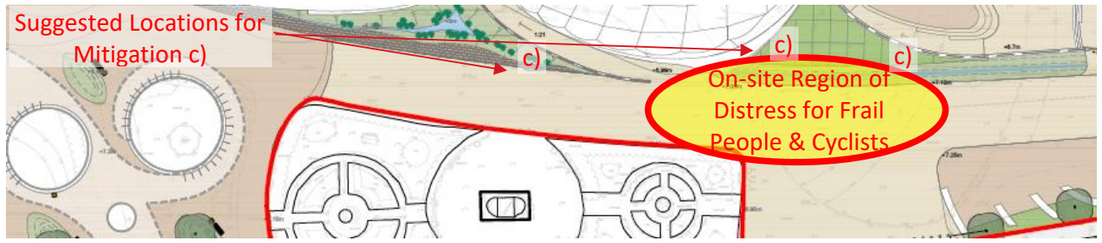


Figure 6.12: Suggested Locations for Mitigation c)

6.4.1.4. Mitigation Location d)

Mitigation is likely to be required at Pedestrian Distress Location 3) “At the southeast corner of the site”

It is not straightforward to provide local shelter from east-west winds to an east-west route without obstructing the pedestrian flow. The only on-site locations for tree planting in this area lie to the north, across the footbridge.

One of the pedestrian crossings identified in section 6.2.2 (within an existing off-site region of pedestrian distress for frail people and cyclists) lies to the southeast of this region. The provision of off-site trees or other local shelter to the north of this crossing would improve both issues simultaneously.

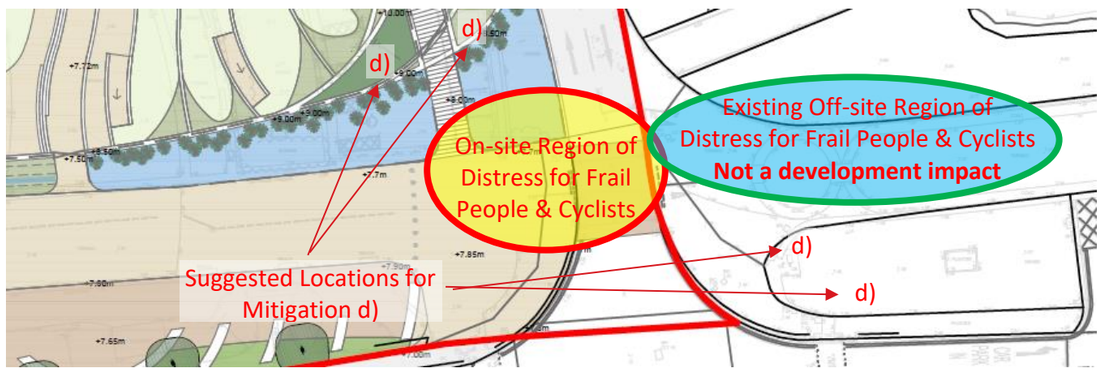


Figure 6.13: Suggested Locations for Mitigation d)

7. Conclusions & Recommendations

7.1. Introduction

A new landmark leisure development is proposed for the Seafront Headland, Central Promenade, north of Marine Road Central in the town of Morecambe.

Hilson Moran has been appointed by the developer, Eden Project International Ltd, to provide a quantitative wind microclimate assessment for the proposed development against the widely used Lawson Criteria. The analysis considers two scenarios: Existing, & Proposed, using CFD simulations from 36 wind directions.

7.2. Effects of the Proposed Development

7.2.1. Comfort

As detailed in section 6.1 and Figure 6.2, simulations show that, following the development, the conditions in all regions continue to be milder than the existing conditions, and milder than the required comfort threshold in most locations. Simulations show six regions in which conditions are likely to be not "acceptable" according to the Lawson pedestrian comfort criteria for the intended activities. After accounting for panoramic locations and the proposed landscaping strategy, there are four remaining regions which would require mitigation, in the form of increased soft landscaping.

7.2.2. Distress

As described in section 6.2, simulations show no regions of pedestrian distress for general users within the assessment area for either the existing or proposed scenarios.

As detailed in section 6.2 and Figure 6.4, simulations show that, following the development, no new regions of distress for frail pedestrians and cyclists are introduced offsite within the assessment area, although some large off-site regions still remain, including the locations of two pedestrian crossings on Marine Road Central. Lancaster City Council may wish to consider providing additional local shelter for these crossings.

Simulations show three on-site regions of distress for frail pedestrians and cyclists. After accounting for alternative routes and the proposed soft landscaping, there are two remaining on-site regions which would require mitigation, in the form of increased soft landscaping.

7.2.3. Mitigation

Section 6.4 provides details of locations where additional local shelter through soft landscaping would provide improved wind microclimate conditions for each region where mitigation would be required. A site-wide summary of these locations is indicated in Figure 7.1.

Table 7.1: Summary of Mitigation Requirement Locations

ID	Location	Criteria
a)	Two seating regions overlooking the seafront	Pedestrian Comfort
b)	Two seating regions in the southwest of the site	Pedestrian Comfort
c)	At the southeast corner of the main building	Pedestrian Distress for Frail People or Cyclists
d)	At the southeast corner of the site	Pedestrian Distress for Frail People or Cyclists

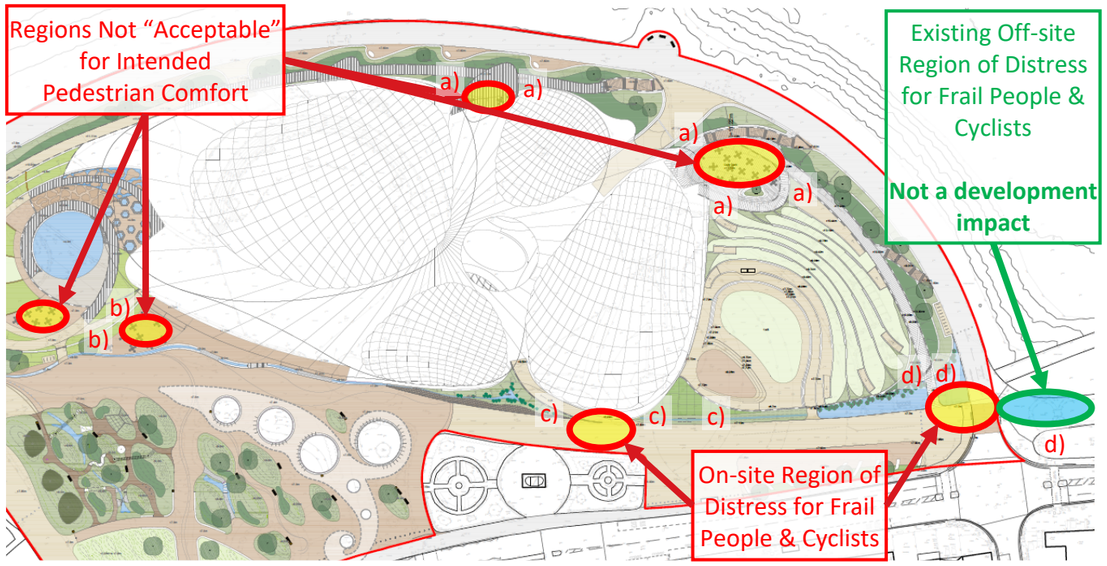


Figure 7.1: Summary of Suggested Locations for Mitigation Requirements a), b), c), & d)

7.3. Conclusions

Simulations show that the impact of the proposed massing is likely to be **beneficial** to the off-site pedestrian wind microclimate for both comfort and distress. After accounting for other effects, including panoramic location, alternative routes, and the proposed landscaping strategy:

- Four locations are unlikely to achieve the required **comfort** conditions;
- Two locations are unlikely to achieve the required **distress** conditions for frail people and cyclists;
- Some significant existing off-site regions of distress for frail people and cyclists will remain, including the locations of two pedestrian crossings on Marine Road Central.

Additional local shelter through soft landscaping would provide improved wind microclimate conditions for each region where mitigation would be required, as summarised in Figure 7.1.

Appendix A – EDNN-TEP-ZZ-ZZ-DR-LA-001-Landscape General Arrangement_DRAFT_10.08.21 (002).pdf