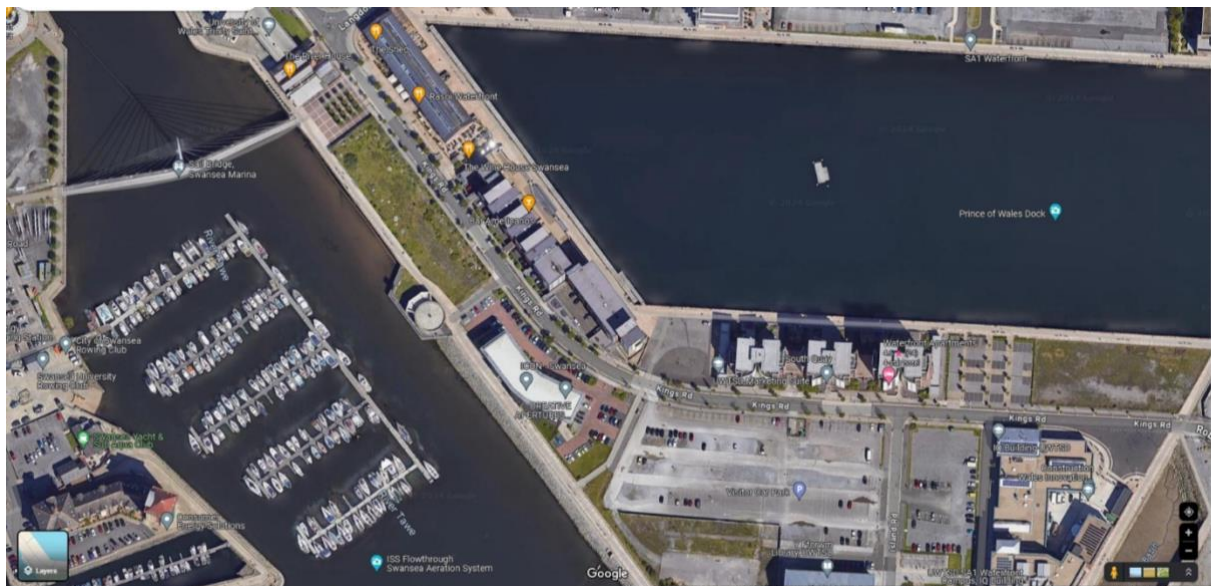


SUSTAINABILITY EVALUATION

Assignment 2 ACBA5019



Curtis Richards (2309713)

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1. INTRODUCTION

This report will build upon the design and discussions from '*Assignment 1*' of this module, therefore the reader is required to refer to the previous report for context and detail relating to the design proposal and selected methods of construction.

Whereas *Assignment 1* focussed on the design and construction methods, *Assignment 2* will consider the sustainability of the building. This report does not aim to alter the structural elements of the previous design, alternatively it will analyse the advantages and limitations to the design and if any additional elements could improve its sustainability.

Following the introduction, three primary sections will evaluate the design in accordance with its environmental impact, façade greening and SuDS, and flexibility in design and use. Moreover, the three sections will be further divided to consider the sub-elements that contribute these overarching measurables such as but not limited to its aesthetics, life cycle, and orientation.

2. ENVIRONMENTAL IMPACT

Arguably, the principal concepts when considering sustainability are the environmental impacts. Sustainability comprises environmental measures, although it is not limited to environmental matters, these will be outlined in this report.

2.1 Orientation

Whilst not always a primary environmental focus, building design should optimize its surroundings. The building's orientation affects internal comfort by influencing solar gain, wind pressure, and natural light, all of which vary seasonally.

In the Northern Hemisphere, solar gain is beneficial during colder months but should be minimized in warmer seasons. A well-designed building can reduce energy consumption and costs. However, in Swansea's climate, solar losses often outweigh gains (*McMullan 2007*), suggesting the need for more careful design in solar-sensitive climates.

To maximize solar gain, a building's orientation ideally aligns to maximise the sun's position. In summer, the sun's rays penetrate at steeper angles with longer daylight, whilst in winter, daylight is shorter, with shallower sunlight angles (*figures 2.1 & 2.2*). Additionally, UK guidance recommends that South, West, and East facades all receive at least one hour of direct sunlight on March 1st (*McMullan 2007*), which is incorporated into the building's orientation.

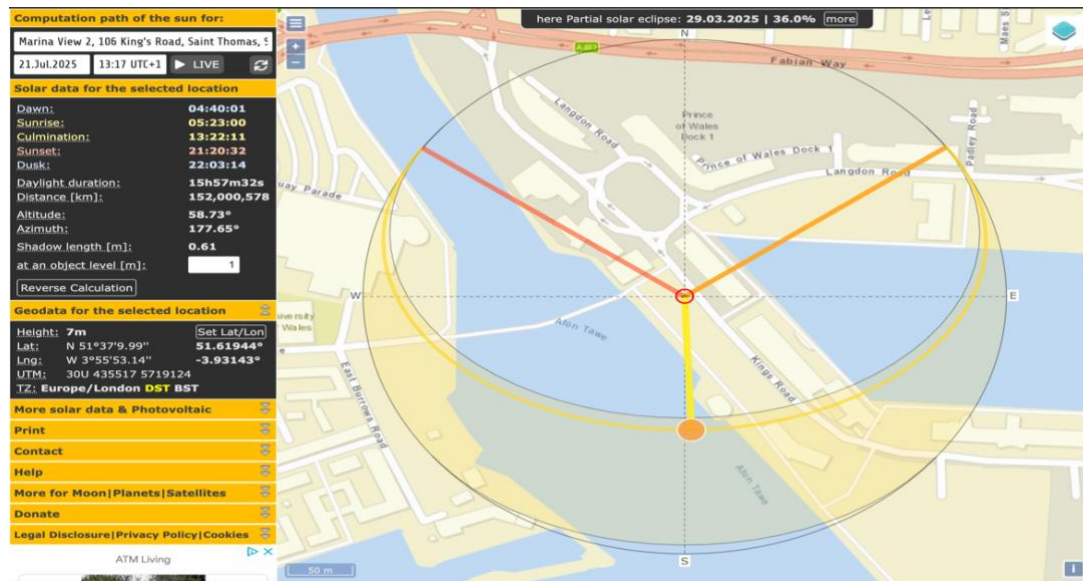


Figure 2.1: Caption displaying the effect of the summer solace on the Prince of Wales Dock (SunCalc 2025)

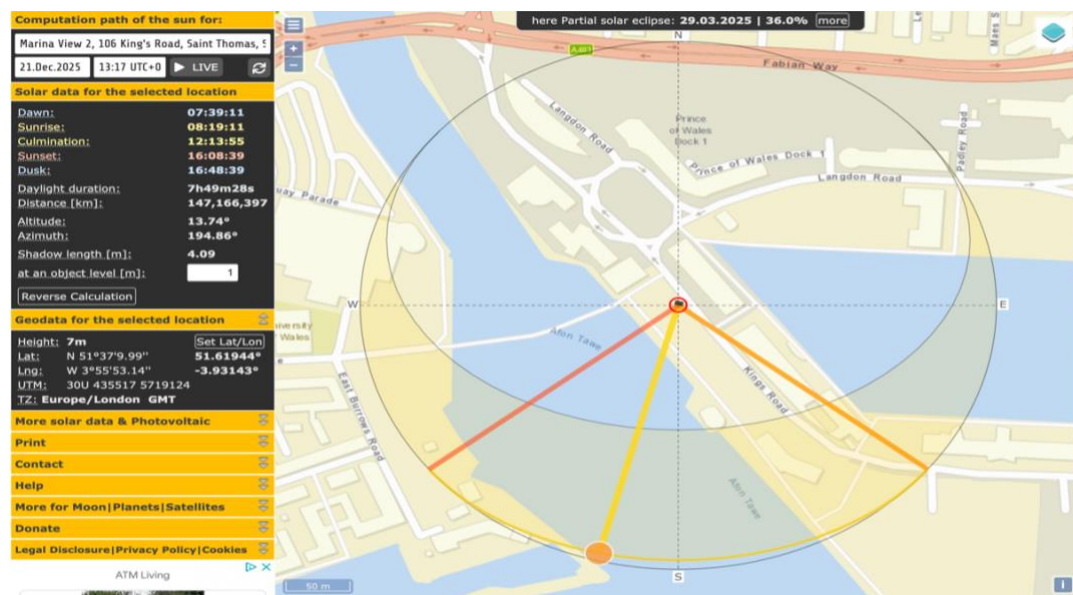


Figure 2.2: Caption displaying the effect of the winter solace on the Prince of Wales Dock (SunCalc 2025)

Due to the constrained boundary, the development forms the orientation shown in figure 2.3. This ensures annual prolonged sunlight, especially on the South-East to South-West façades, with maximum sunlight reaching the North-East to North-West facades during summer. Moreover, the sun's angle is 45° steeper during summer solace than in winter solace, generating increased solar radiation.

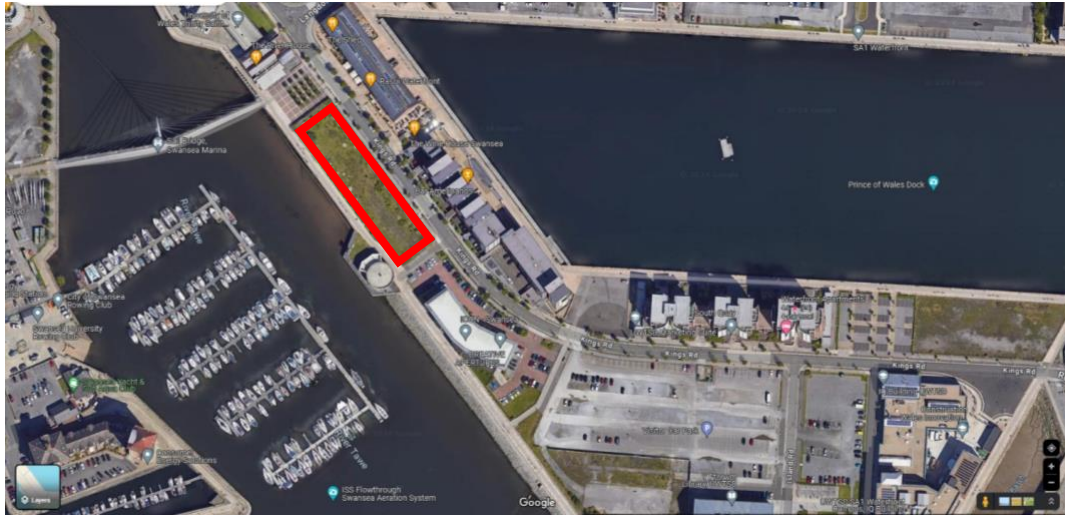


Figure 2.3: The geographic location of the building orientation in the Prince of Wales Dock

Extensive curtain wall façade (*Appendix A*) will maximise solar gain, which would contribute towards the energy efficiency especially throughout the winter months. Equally, it is essential to minimise summer solar gain to reduce the reliance on air cooling systems and energy consumption. The evidence therefore recommends brise-soleil at precise angles to minimise summer radiation from steep angles but simultaneously permits radiation at shallower angles during the winter. Moreover, solar control integrated within the glazing could be incorporated to further control solar gain.

Direct radiation coincides with the quantity of direct light, therefore the building will receive high volumes of direct sunlight to the Southern façades, eventually extending to northern façades towards the summer. The building's narrow shape permits sunlight to extend East to West, but this is restricted to an open-plan space like the ground floor (*Appendix A*). Evidently, natural light is more seasonally dependant in the partitioned private living zones on the upper floors, requiring additional artificial lighting.

The orientation and design of the building enhances its energy efficiency but weakens its mitigation to wind. Foremost, the site restricts the structure to a tall, rectangular object to maximise the geographical capacity. It is paramount to acknowledge the design limitations to mitigate possible wind effects.

Finally, altitudinous structures generate a ‘vortex’ effect diverting wind around the structure before returning on to the opposing façade (Chudley and Greeno 2006) (Figure 2.5). This phenomenon is likely to develop on the Easterly façade, especially as no natural barriers exist to deflect wind. Further design and wind simulations are required to assess wind impact and any alterations that could alleviate wind pressure and the aerodynamic relationship to the surrounding landscape.

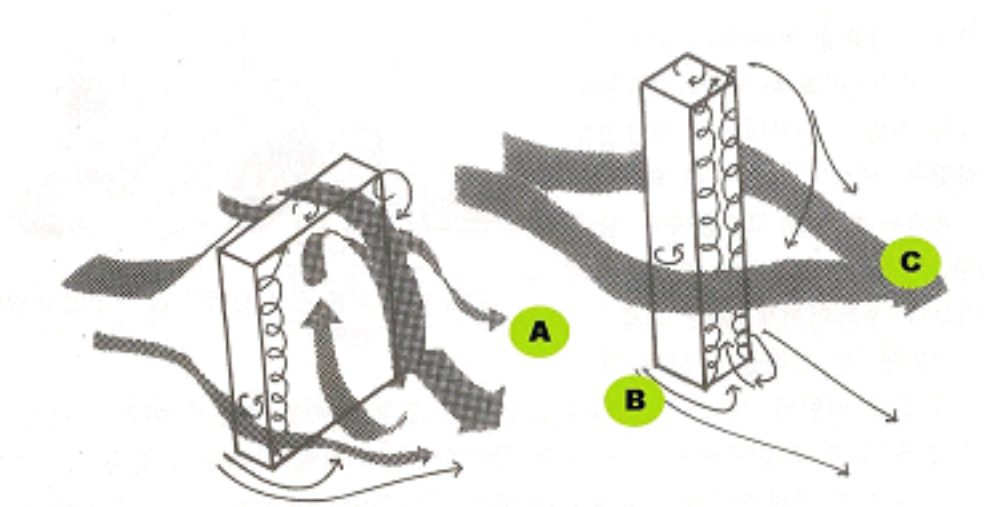


Figure 2.5: The various vortex effect of wind on buildings: A – Vortex Flow; B – Corner Stream; C: through flow (Kim et al., 2007)

2.2 Life Cycle

Understanding carbon uptake is key to a building’s life cycle. It includes operational, embodied, and user carbon—relating to energy use, construction, and end-user consumption, respectively. Embodied carbon is assessed through raw materials, production, transport, lifespan, and deconstruction (McMullan 2007), while operational carbon depends on renewable energy use and material sustainability. BREEAM and Net Zero are common targets in Wales which rely on the renewable energy sources and reductions in carbon.

To analyse whole life carbon, assessors utilise the '*Whole Life Carbon Assessment*' (WLCA) which should be incorporated from the beginning of planning and design and updated as the project evolves until completion. The WLCA individually tallies the embodied, operational, and user carbon to produce an overall value. Due to the scope of this report, the WLCA will not be calculated however a brief assessment follows to identify key features concerning the WLCA.

Steel comprises most of the structural frame, a 'sustainable' and adaptable material, albeit the production of steel produces carbon emissions. Steel can span greater distances without intermediate propping compared to a concrete frame thus requiring less material. Concrete does not possess coequal adaptable or sustainable characteristics as steel, it is usually limited to being crushed down and reused as aggregate therefore steel is considered more sustainable despite its manufacturing process producing CO₂.

Furthermore, the building's panelised curtain wall system enables the façade to be easily adapted without complete demolition. The double-glazed units equipped with solar control enhances the building's operational performance (*Chudley and Greeno 2006*). The building is complete with an aluminium capped roof, with solar panels which furthers the building's recyclability and decarbonisation.

2.3 Aesthetics

Aesthetics are subjective to the individual therefore a design will not guarantee 100% approval, consequently one can pose does the functionality supersede the appearance? As discussed in *assignment 1*, the surrounding urban landscape influenced the external aesthetics however the design aims to incorporate unique features to bestow an architectural personality upon the development.

Ultimately, *Riley and Cotgrave (2004)* suggests that the importance of the aesthetics is determined by the end-user and locational geography. To simplify, inner-city

developments would place greater emphasis on aesthetics than an outer-city industrial unit, moreover the design should appeal to the individuals that will be frequenting/occupying the development.

The external envelope holds aesthetic significance, as it is the face and first impression. *Riley and Cotgrave (2004)* and *Chudley and Greeno (2006)* emphasise the significance of flexible finishes because of their adaptable characteristics. Crucially *Chudley and Greeno (2006)* also identifies their adjustability to legislative changes concerning acoustics, fire, and thermal ratings that may threaten the building's compliance to modern standards.

3. Urban Greening

Façade greening is a mechanism to improve biodiversity, drainage, and aesthetics in the urban environment. Unfortunately, the current stock of green naturogenic and anthropogenic systems are not sufficient to equal the rate of urbanisation (*Collins, Schaafsma, Hudson, 2017*). This section discusses the benefits of green façades.

3.1 Green Roofs

A green roof is a sandwich of structural, insulative, waterproof and vegetative layers capable of reducing stormwater runoff. These systems are installed on flat-low pitch roofs, with additional structural supports to withstand the increased water loading. Secondary benefits include improving acoustic performance (*Lyons 2007*) and increasing the overall lifespan of roofs as vegetative layers protect against UV light.

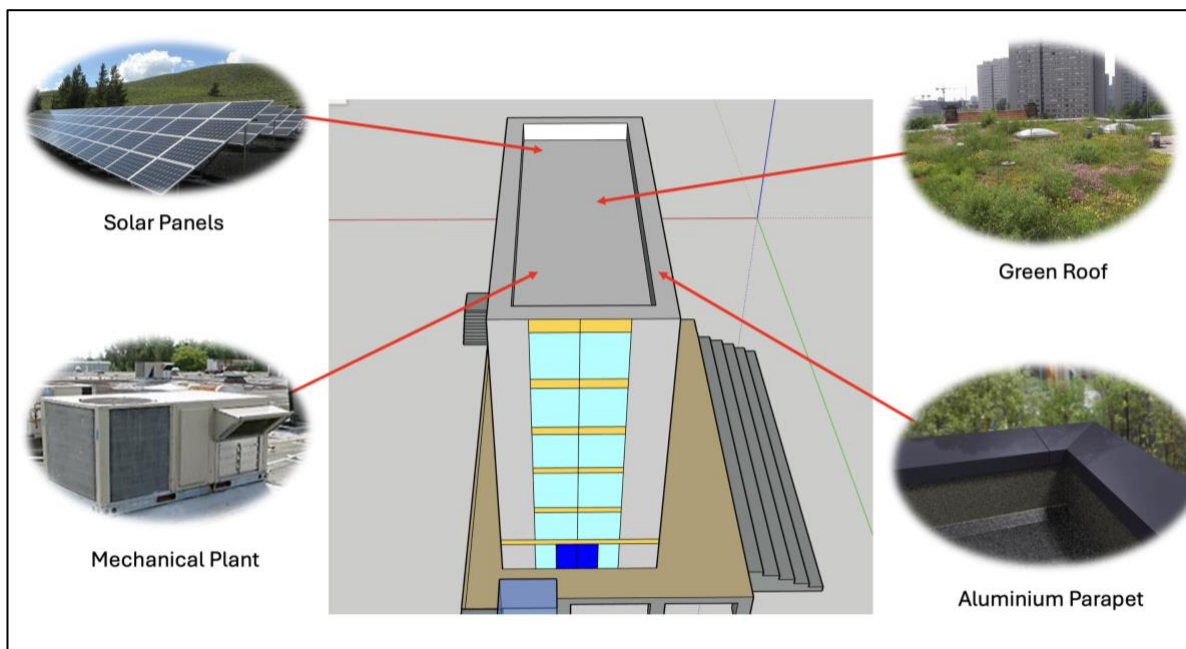


Figure 3.1: A view of the proposed green roof design

A green roof was included in the design (*Figure 3.1*) to support the SuDS calculations in Section 3.2. While the building's height and lack of nearby greenery may challenge biodiversity attraction, it's a vital first step towards creating a sanctuary. Many green roof types exist, including '*Intensive Green Roofs*' that support leisure use and diverse flora but require additional structural support (*Lyons 2007*). This design proposes a standard green roof suited for vegetation, solar panels, and maintenance access.

3.2 Green Façades

Green façades replicate the primary principles of a green roof, albeit to varying degrees. They may not produce a comparable water storage capacity, however their ability to shade and evapotranspiration reduces heat gain, although the extent of this is dictated by the foliage density, plant species, and coverage (*Convertino, Vox and Schettini, 2021*). Commonly, green façades are presented as green walls or living walls; where plants are either potted and grow/climb vertically, or the root systems are embedded into the façade respectively (*Cameron, Taylor, Emmett, 2013*).

Albeit not part of the original design, a green façade could be easily implemented. Numerous studies support this, including *Cameron, Taylor, and Emmett (2013)*, who discovered living walls reducing wall temperatures in China, and the influence of plant species and airgaps on cooling rates in Japan and the Netherlands. Their UK research found similar results, emphasizing vegetation type and transpiration as key cooling factors

Aesthetically, *White and Gatersleben (2011)* study confirmed the aesthetic appreciation for greenery on buildings, particularly Ivy albeit their study was conducted on houses but this report assumes that the fundamental theories still apply. Nevertheless, it is critical that the selected vegetation are adaptable to the local climate and serves their functional purpose in addition to being aesthetically pleasing.

3.3 SuDS Calculations

SuDS is a mechanism to regulate stormwater runoff (*CIRIA 2015*), and in Wales it is a legal requirement for any new buildings $>100\text{m}^2$. This section will analyse the runoff rates and storage capacity of the principal surface types on the proposed site. *Figure 3.2* presents the surface type distribution to be read in conjunction with the concept design sketches in *Appendix A*. Refer to *Appendix B* for calculations.

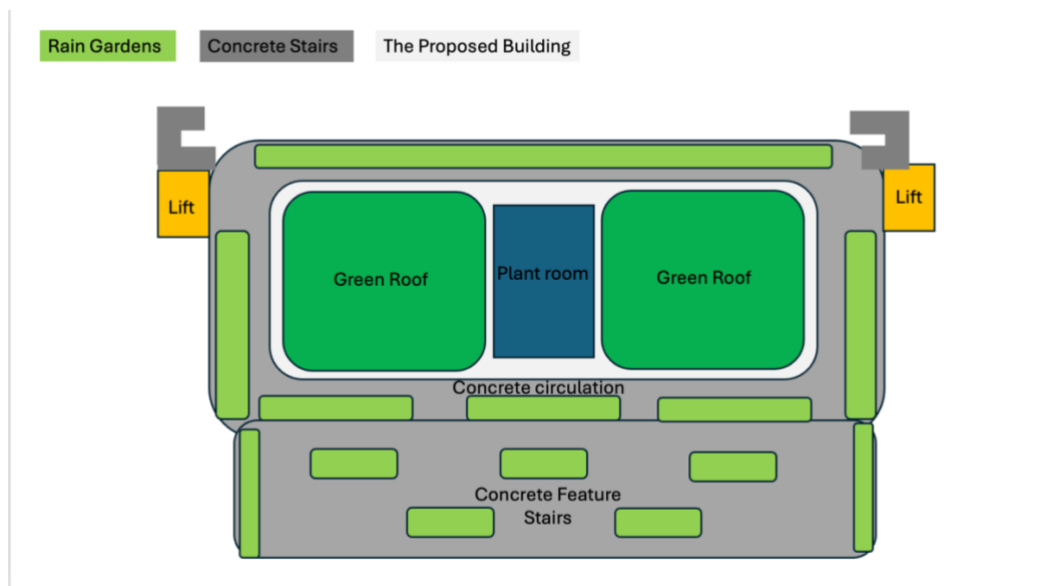


Figure 3.2: A Birdseye diagram detailing the geographical distribution of surface types across the proposed development

SuDS utilise the default greenfield runoff rate to assess the natural runoff compared to the artificial runoff (*CIRIA 2015*). The peak runoff calculations produced a difference of 28.41l/s , multiplied by 3600 seconds (*Appendix B.3*) to calculate the required storage volume ($102.28\text{m}^3/\text{hr}$) for 1hr of rainfall across the site. Meaning that the site must retain 102.28m^3 of rainfall over a 1hr period until stormwater begins to discharge to drainage systems.

To assess the storage capacity, the development was divided to three key surface types, green roof, rain gardens, and permeable paving as these are designed to retain

stormwater. Each individual surface was calculated using the formula in *Appendix B.4*, forecasting a total storage volume of 529.77m³.

The sum of 529.77m³ exceeds the required 102.28m³ to satisfy SuDS, denoting that this development can retain the stormwater of a 5hr storm until water begins to discharge to local drainage. Not all surface types were measured in these calculations, therefore a further study is required to accurately account for all aspects of the development which is beyond the scope of this report.

Important to note that SuDS systems offers additional positive outputs concerning whole life valuations, value engineering and avoided future costs (*CIRIA 2015*).

4. FLEXIBILITY IN DESIGN AND USE

Sustainability is not limited to the construction elements, but also how the design facilitates alternative uses and designs.

4.1 Design

4.1.1 Steel Frame

The proposed development is constructed largely from a steel frame system, which can span long distances to facilitate a communal open-plan zone, which nowadays is a common design in commercial builds facilitating the subdivision and reconfiguration of open-plan spaces (*Riley and Cotgrave 2004*).

4.1.2 Partitioning

The subdivision of internal spaces utilised a steel partitioning system. A metal frame system is lightweight and adaptable as it can be dismantled due to its non-loadbearing properties and potentially reinstated with limited damage, however the damage potential is dependent on the material of the partition where steel would outperform timber (*Chudley and Greeno 2006*).

Moreover, the flexibility of the system is adaptable to everchanging building regulations be it acoustic or fire standards. For example, a flexible partitioning system can alternate to increase the number of plasterboards or type of plasterboard i.e., to include fireboards. Nevertheless, the system is not indispensable as the framing channel utilised may need increasing to add more internal insulation or increase the integrity of the frame for additional plasterboards.

4.1.3 Ceiling Finishes

The design incorporates an exposed soffit in the communal area and a suspended ceiling to the residential zones. Like the partitions, these systems offer design versatility (*Chudley and Greeno 2006*). An exposed soffit is simply a ceiling without a finish; therefore, it facilitates the addition of a new finish and redirection of services whilst suspended ceilings are fixed using suspension hangers to the underside of a metal deck causing limited damage to remove and replace.

4.1.4 External Envelope

As previously discussed, the curtain walling is a panelised jigsaw of glazing and cladding, capable of reconfiguration to exploit natural light and secure privacy where required.

4.2 Future Alternative Use

Evidently, the selected construction methods provide the building with adaptable systems and assuming the structural core and foundations are preserved the following section discusses these potential alternative uses.

The building could maintain its social-habitable core to accommodate hotel or private apartment functions. The existing layout would require limited reconfiguration, albeit an increase in private spaces (m²) thus reducing the number of individual rooms. The open-plan floor could be maintained for social, reception, or communal services use. Although, the provision of additional mechanical and electrical services may be extensive to provide private kitchens and bathrooms in comparison to the shared facilities found in student accommodation.

Alternatively, UWTSD could occupy the space for educational purposes. The partitions can be reconfigured to create larger lecture and seminar rooms, whilst providing leisure and study spaces in the existing communal floor. This scheme could be considered

simplistic to implement, despite the extent of reconfiguration because of the adaptable characteristics of the existing partitions on the upper floors and the exposed soffits on the lower level. Additional WCs would be necessary, although the magnitude of new services would be minimal in comparison to the required services for private living spaces.

5. CONCLUSION

This report expands on the proposed design from *Assignment 1*, with a greater focus on its sustainability. Overall, the design adheres to many of the essential principles that encompasses sustainable design. The orientation, although limited by site constraints, enhances natural light and solar gain, although the orientation will pose challenges concerning solar gain control, wind loading, and wind vortex.

Aesthetically, the curtain wall and cladding finish is very representative of the urban locality however this report has outlined beyond their visual appeal these systems are also adaptable to the building's requirements and can be manufactured from recyclable materials. Likewise, the internal partitioning possesses similar sustainable characteristics especially when metal framing systems are utilised, both supporting future alternative uses. Additionally, a basic exercise concluded that the proposed design would satisfy SuDS, and although no WLCA was conducted it is apparent that the design features several sustainable proposals.

In sum, the design has incorporated numerous sustainable methods and materials to minimise its current and future environmental impact, however this report also acknowledges its design limitations and encourages further investigation to limit the potential wind impact and how a green façade could benefit the building's functionality.

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6. APPENDICIES

6.1 Appendix A – Concept Design

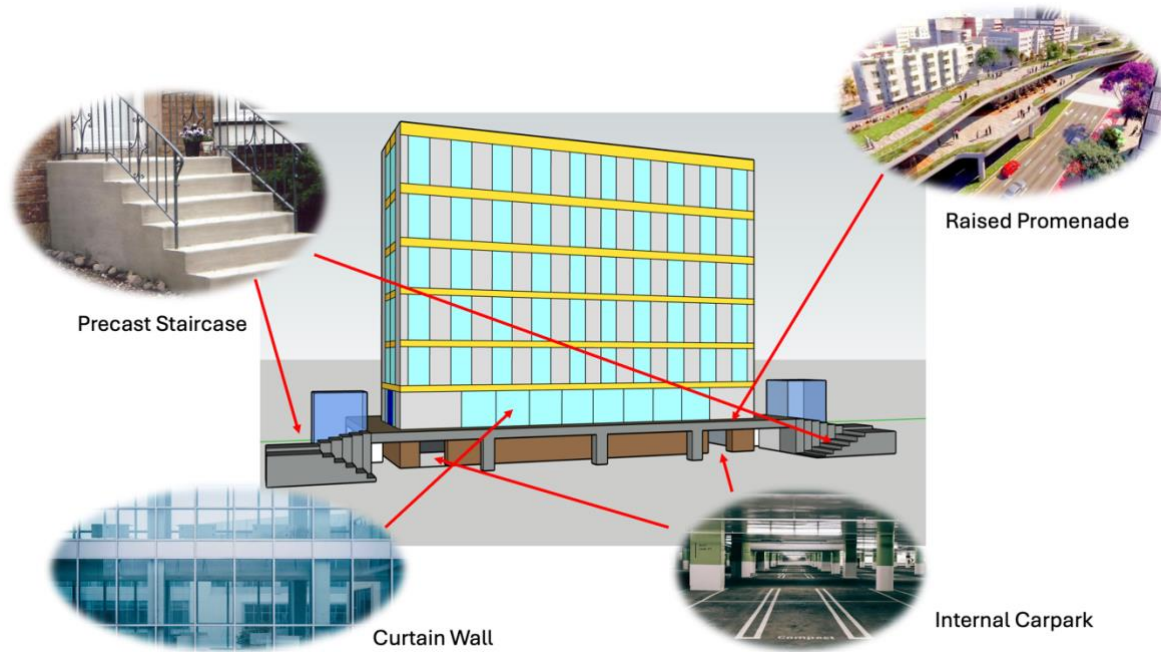


Figure 6.1: East Elevation

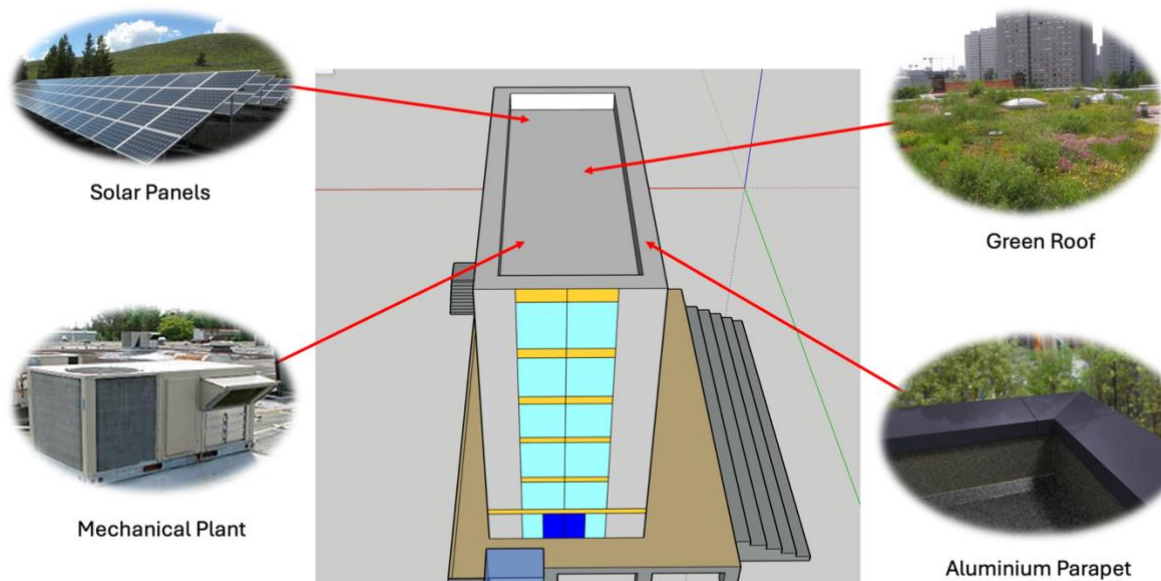


Figure 6.2: North Elevation

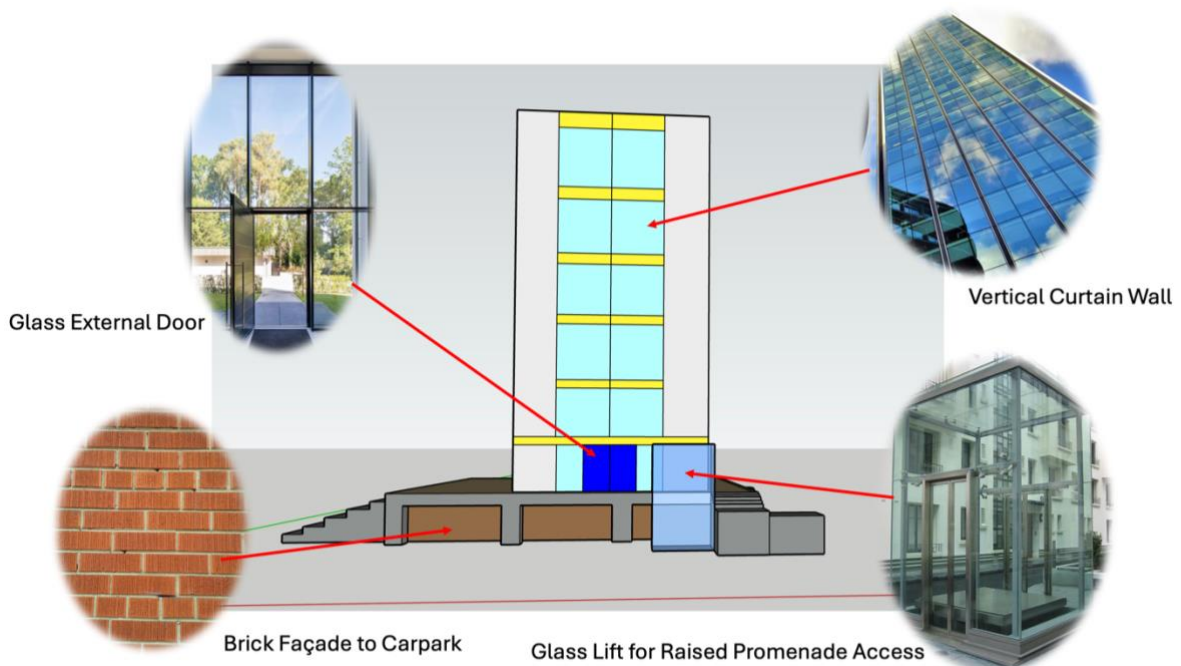


Figure 6.3: South Elevation

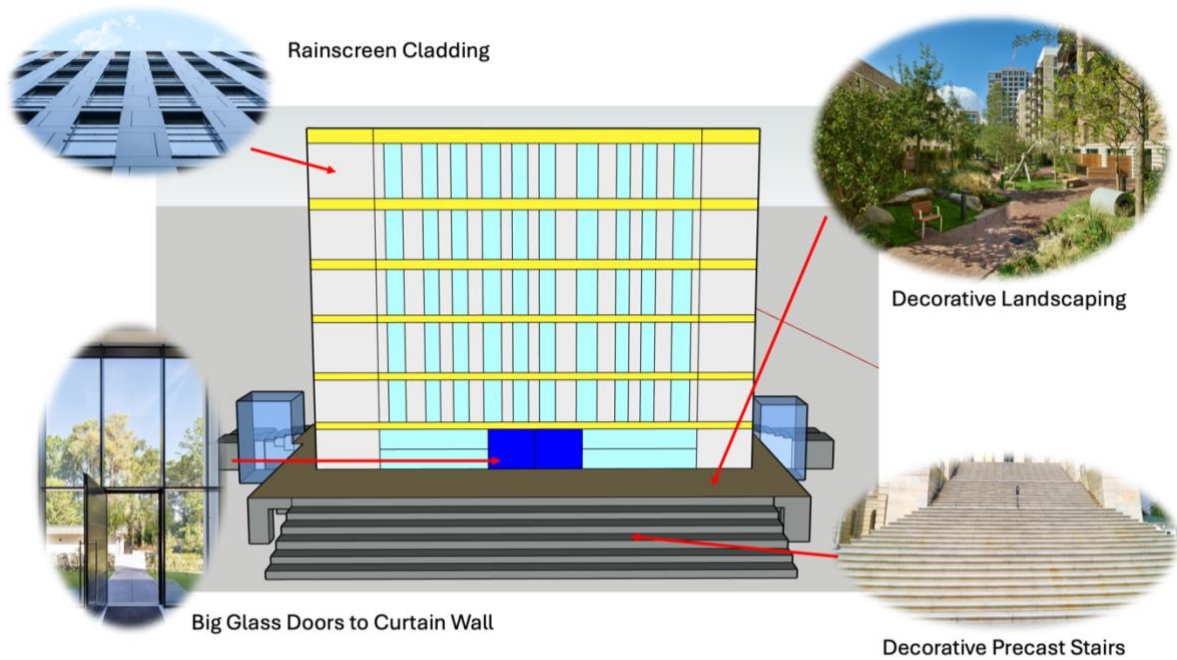


Figure 6.4: West Elevation

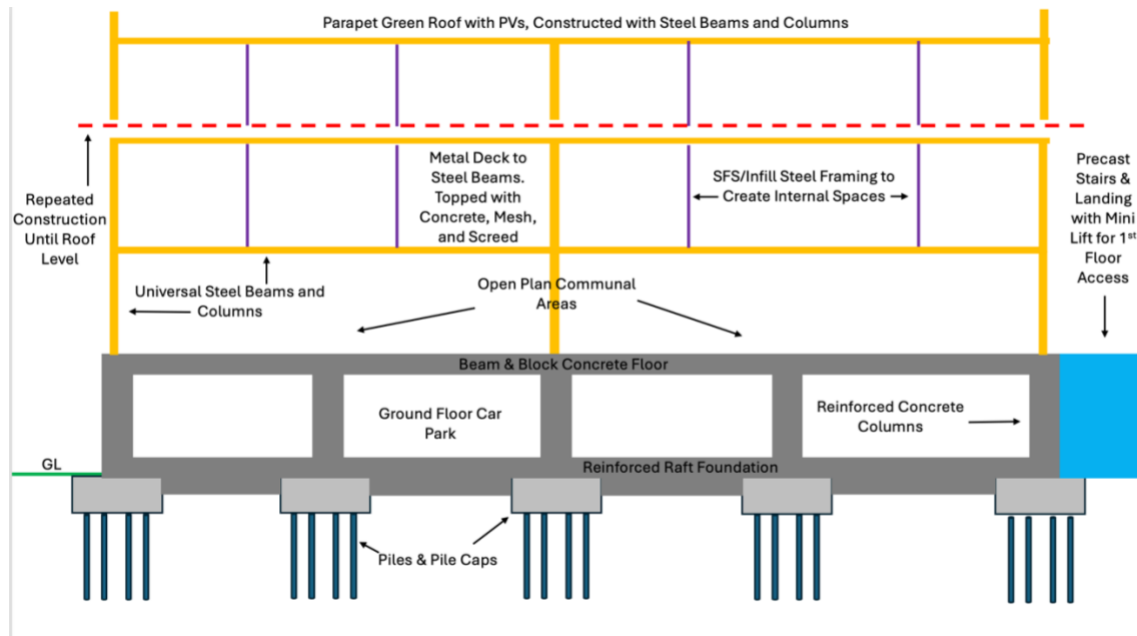


Figure 6.5: The frame layout and internal partition

6.2 Appendix B – SuDS Calculations

Appendix B.1 – Peak Runoff Calculations

Table 6.1: Calculating the peak runoff rates for the proposed development surface types

Building Elements	2.78 Conversion	Runoff Coefficient	Rainfall Intensity (mm/h)	Catchment Area (hectares)	Peak Runoff l/h	Litres/s
Green Roof	2.78	0.6	17	0.1904	19,436.34	5.40
Footpaths	2.78	0.6	17	0.27	27,562.03	7.66
Stairs	2.78	0.6	17	0.09	9,187.34	2.55
Aluminium capping and plant room	2.78	0.95	17	0.346	55,923.70	15.53
Total Run-off Rates					112,109.42	31.142

Appendix B.2 – Qbar Calculations

$$Qbar = 0.00108 \times Area^{0.89} \times SAAR^{1.17} \times SOIL^{2.17}$$

Figure 6.6: Qbar Equation

Qbar - 50 Hectar Site		
Area	50 ha	
SAAR	1136 mm	
SOIL Index	<u>0.37</u>	
Qbar - 50 ha	0.25 m ³ /s	
	<u>50 ha</u>	Divide
Qbar - 1 ha	0.00506 m ³ /s	
	<u>0.54 ha</u>	Multiply
Qbar - 0.54 ha	0.00273 m ³ /s	
	<u>1000 l</u>	Multiply
Qbar - Site	<u>2.73 l/s</u>	

Figure 6.7: Qbar calculations converted from a 50ha area to a 0.54ha area

Appendix B.3 – Required Storage Volume

<u>Estimated storage volume required</u>		
Total Runoff Rate of Building Components	31.14	l/s
Inflow rate / Peak runoff	31.14	l/s
Outflow rate / Greenfield Runoff	2.73	l/s
Duration = length of storm	<u>3600</u>	Seconds
Litres	102,281.42	l/hr
m3	102.28	m3/hr

Figure 6.8: Storage volume required to retain the volume of rainfall produced in a 1hr storm across the proposed site

Appendix B.4 – Subdivision of Surface Types

<u>DIVISION OF LANDSCAPE TYPES ACROSS THE SITE</u>		
	m2	
Hard Landscape	2700	
Raingarden	<u>1620</u>	Aim for 60% green space 'rain garden'
Concrete Stairs	900	
Raingarden Space	<u>180</u>	Aim for 20% raingarden
Total Rain Garden	1800	
Net Hard Landscape	1800	Remaining m2 after the rain garden m2 deduction
Permeable Paving	900	Aim for 50% Permeable paving from the remaining hard landscape
Total Roof	2024	
Plant room 6 x 20m	<u>120</u>	
	1904	Total Green Roof

Figure 6.9: Subdivision of landscape on the proposed site to calculate the total storage volume of the proposed development

Appendix B.4 – Storage Volume

Soil

$$V_s = V \times SVP(1-VFC)$$

Figure 6.10: The equation used to calculate the storage capacity (m3) of surface types

Table 6.2: Calculating the storage volumes for the three predominant surface types across the proposed development

Surfaces	Area (m2)	Depth 1 (m)	Desc.	SVP(1-VFC)	Storage Volume (Depth 1) AREA x Depth x SVP(1-VFC)	Unit	Depth 2 (m)	Desc.	SVP(1-VFC)	Storage Volume (Depth 1) AREA x Depth x SVP(1-VFC)	Unit	Total storage (m3)
Rain Garden	1800	0.45	Soil	0.26	210.6	m3	0.1	Gravel	0.255	45.90	m3	256.50
Green Roof	1904	0.05	Green roof mix	0.15	14.28	m3	0.1	Geocomposite layer	0.5	95.20	m3	109.48
Permeable Paving	900	0.35	Gravel	0.255	80.325	m3	0.475	Sub-base	0.195	83.36	m3	163.69
Total												529.67

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