

Green Spaces and Biodiversity

SWANSEA COUNTY REGENERATION REPORT



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UWTSD

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Introduction 1.0

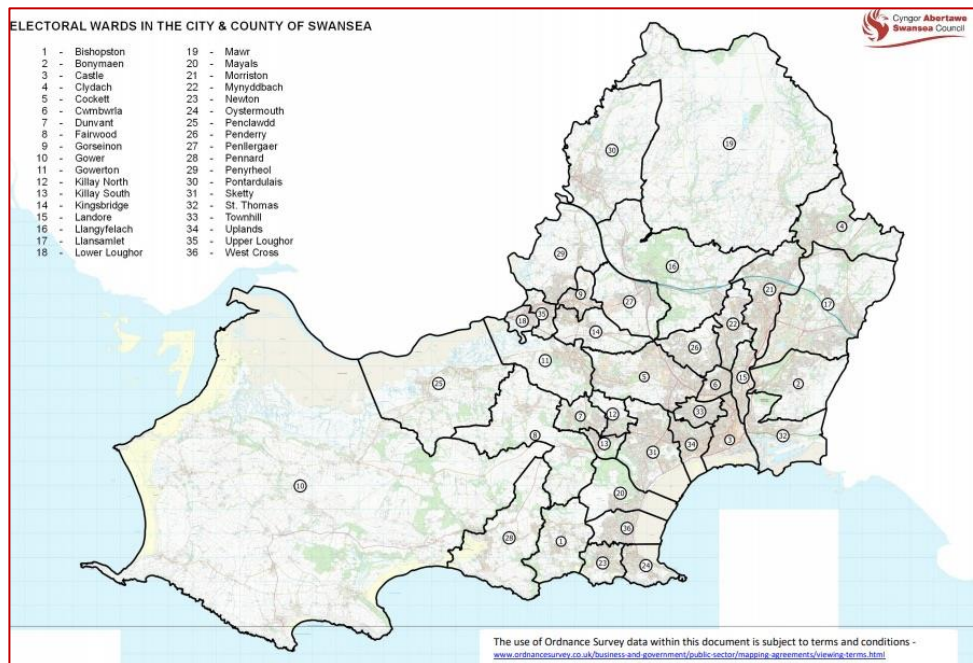


Figure 1 Map of Swansea County

Swansea County 1.1

Swansea, a coastal city, is the second largest in Wales with almost 4 million people visiting in 2018, spending £447.74 million, making tourism a key factor economically (Swansea Council, 2020). The city, aiming for the 2021 city of culture bid, is considered a university city with two universities offering varying ecologically based courses with particularly good marine biology facilities. The city centre itself is unique in Wales, being located on the waterfront with a 5 mile stretch of sand at the forefront and a SSSI for seabirds, particularly migratory seabirds such as Sanderling, Ringed Plovers and Oystercatchers (Swansea Council, 2019a).

Within the county (fig 1) there is around 380 sq. kilometres of land with 69.5% being rural and 30.5 % being urban (Swansea Council, 2020). The county includes the Gower peninsula which was the first in UK to achieve Area Of Natural Beauty designation and within the peninsula are a number of other SSSI's, Ramsar, MSAC and SPA designations. As of 2018, the population stood at 246,500, which increased by 12,300 since 2008. Seventy two percent of working age residents are economically active with the average earnings for full time employees annually standing at around £28,000 as of April 2019. Additionally, 32,600 people commute into Swansea to work, adding to congestion issues (Swansea Council, 2020).

According to the Welsh Index of Multiple Deprivation 11.5% of local areas fell within top 10% deprived in Wales and 5400 people were unemployed as of April 2019 (Swansea Council, 2020). Housing prices are high and appear to attract affluent residents and it is suggested that there are some 1,800 second homes - mostly in Swansea West, Gower and Swansea Marina, alongside 4300 people on the housing register in need of housing (Youle, 2019).

Green Spaces and Biodiversity 1.2

It is becoming more and more widely accepted that cities with greater green spaces and biodiversity have the additional benefit of better air and water quality as well as mental health and wellbeing of citizens (Forest Research, 2010). Studies have found its best for people's wellbeing to live within 400m to 500m of an open space, while just the sight of vegetation lowered blood pressure (Bell. S *et al.*, 2008). In a city with an ageing population the addition of green spaces can be used as a prescription for better health and lowers the pressure on NHS health care costs and lowers increasing welfare spends due to less people off work and claiming sick benefits, benefiting the city both ecologically and economically (Government Office for Science, 2016; Aronson *et al.*, 2017). Fifty percent of Swansea county is considered of significant ecological importance (Gruffydd, 2019; Swansea Council, 2019c) rendering Swansea in a good position to utilise these ecosystem services in a more dynamic and circular economic way.

The focus for this study is the regeneration of Green Spaces and Biodiversity within Swansea county, the aim is to increase green space intelligently in accordance with targeted utilization of ecosystem services (fig 2) required for specific socio environmental issues such as air and water quality, flooding and wellbeing, working along-side factors such climate change and rising sea levels, changing weather patterns, potential resource shortages, the large declines of wildlife species, growing threatened species lists, the large proportion of citizens experiencing mental health, other health related problems and the impending Brexit, benefitting things like carbon sequestration, flood and air quality control and working cohesively with the future well beings act and the 7 principles (fig3).

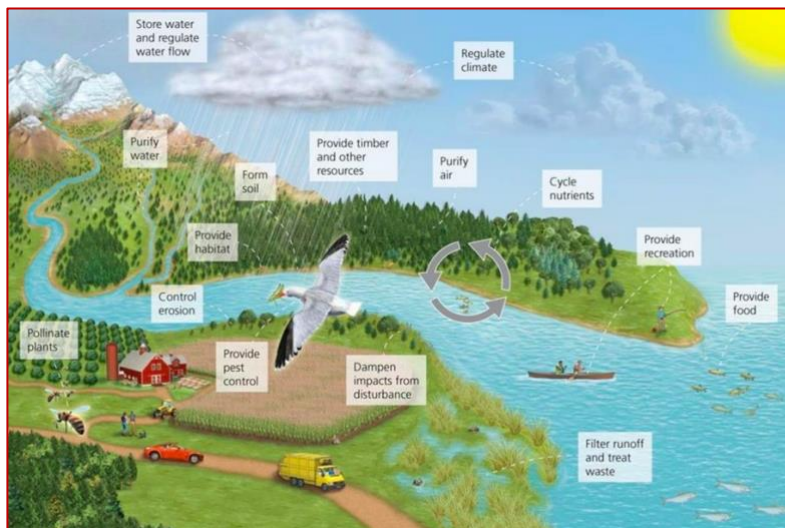


Figure 2 Diagram showing ecosystem services

Policy, Legislation and the Future Well Being Act 1.3

Different policies and legislation provide essential direction to achieve sustainable development and regeneration of the county. These policies offer guidelines to developers and citizens on targets and methods required for future developments. The Well-being of Future Generations (Wales) Act was initiated to improve social, economic, environmental and cultural well-being in Wales (Future Generations Commissioner for Wales, 2015). It aims to work cohesively to guide public bodies, people and communities towards the same sustainably focused vision to create a better Wales and suggests seven well-being goals show below in (fig 3). The well-being objectives published suggest things that the public bodies need to consider and show that they have applied to the sustainable development principle, providing ways to avoid repeating past mistakes and to tackle potential long term challenges (Boaz *et al.*, 2019).

In order to measure success, Indicators must be set with objectives and strategies to provide milestones of expectations. Some key priorities to achieving these strategies are; (Defra, 2005)

- Sustainable Consumption and Production
- Climate Change and Energy
- Natural Resource Protection
- Environmental Enhancement
- Sustainable Communities

Currently there are 40 indicators which are frequently updated to include relevant issues and directing future trends reports (Bryer, 2016). A number of different strategies such as the Tall buildings strategy, the UK green road code of practice, Catchment Flood Management Plans (CFMPs) and Shoreline Management Plans (SMPs) provide insight into best practice solutions within specific sectors, to support the move to more sustainable construction and utilisation of ecosystem services.

Goal	Description of the goal
A prosperous Wales	An innovative, productive and low carbon society which recognises the limits of the global environment and therefore uses resources efficiently and proportionately (including acting on climate change); and which develops a skilled and well-educated population in an economy which generates wealth and provides employment opportunities, allowing people to take advantage of the wealth generated through securing decent work.
A resilient Wales	A nation which maintains and enhances a biodiverse natural environment with healthy functioning ecosystems that support social, economic and ecological resilience and the capacity to adapt to change (for example climate change).
A healthier Wales	A society in which people's physical and mental well-being is maximised and in which choices and behaviours that benefit future health are understood.
A more equal Wales	A society that enables people to fulfil their potential no matter what their background or circumstances (including their socio economic background and circumstances).
A Wales of cohesive communities	Attractive, viable, safe and well-connected communities.
A Wales of vibrant culture and thriving Welsh language	A society that promotes and protects culture, heritage and the Welsh language, and which encourages people to participate in the arts, and sports and recreation.
A globally responsible Wales	A nation which, when doing anything to improve the economic, social, environmental and cultural well-being of Wales, takes account of whether doing such a thing may make a positive contribution to global well-being.

Figure 3 FGWA list of Goals

Swansea County SWOT analysis 2.0

The Swot analysis, alongside further research into literature and local area reports/legislation provided further what benefits could be obtained from an increase in green space for both citizens and biodiversity. The focus after analysis decided upon 4 key targets that could benefit including;

- air quality
- water quality/flooding
- citizens wellbeing and health
- increased biodiversity with a focus on key species such as pollinators and species that can act as potential ecosystem engineers or UK Biodiversity Action Plan (BAP) species.

A recent Regeneration plan formulated by the council aimed to increase terrestrial green infrastructure to 26% by 2030 from its current 13% in city and to increase tree canopy cover by 25% by 2044 (Gruffydd, 2019) and there are many current regeneration projects being actioned within and surrounding the city centre, such as the Hafod brickworks, Kilvey hill skyline development, the digital arena and the greening of the Kingsway (Swansea Council, 2019b). There appears to be a lack of attention to the north end of the city centre and county where there appears more incidents of flooding and generally more deprivation shown via GIS maps provided by NRW(fig 5,6 and 7)

The SWOT analysis undertaken found air quality to be a problem in a number of the north Swansea areas. Both Particulate Matter (PM) 10 and Pm2.5 readings for ozone are above required levels at CWM level and St Thomas (Price, 2019). Areas around sketty, forest fach and busy junctions from congestion also have been found to exceed emissions levels indicating they could benefit from green infrastructure and natural ecosystem services such as increasing trees and selecting species with greater capacity for carbon sequestration.(Fig 4) provided by Swansea Annual Progress Report 2018 shows the NO₂ readings showing a downward trend over the last 5 years but in certain locations such as the Hafod (Site CM4) and High street near the Train station (city centre Site CM11) , there are still exceedances of the recommended annual mean objective concentration of 40 ug/m³(Price, 2019)

Site ID	Site Type	Monitoring Type	Valid Data Capture 2017 (%) ⁽²⁾	NO ₂ Annual Mean Concentration (µg/m ³) ⁽³⁾				
				2013	2014	2015	2016	2017
CM1**	Roadside	Automatic	98.63	26.8 (31.15)	25 (30.76)	23 (27.43)	24.4 (30.37)	20 (24.41)
CM2**	Roadside	Automatic	91.63	23.2 (28.58)	21.1 (25.89)	20.5 (25.02)	22.3 (29.69)	20.6 (29.14)
CM3	Urban Background	Automatic	90.73	18.54	17.08	14.75	16.39	13.41
CM4	Façade	Automatic	95.34	50.68	48.99	40.24	45.59	40.04
CM5	Roadside	Automatic	99.14	39.45	35.83	33.71	35.83	32.19
CM11**	Roadside	Automatic	98.66	N/A	56.85*	50.9 (54.52)	48.3 (51.76)	44 (47.20)
CM12	Roadside	Automatic	25.7	N/A	N/A	N/A	N/A	25.73***

Site ID	Site Name	Site ID	Site Name
CM1	Swansea Roadside AURN	CM7	Uplands Crescent
CM2	Morrison Groundhog	CM8	Sketty Cross
CM3	Cwm Level Park	CM9	Westway Quadrant Bus Station
CM4	Hafod Doas	CM11	Station Court High Street
CM5	St Thomas DOAS	CM12	Morfa Road
CM6	Fforestfach Cross	CM13	SA1 Junction Port Tennant

Figure 4 Table to show Annual Mean Concentration for continuous monitoring sites with legend to understand site location

In other areas, both surface water flooding, as shown on a GIS map with an NRW spatial map overlay with data for the area (fig 5), and river and sea flooding (fig 6) are of greater concern, again more prominently in the North of the City and County though present within some city center areas and could benefit from green infrastructure to manage the overflow, particularly with the potential for further increased flooding with ongoing climatic change to take pressure of CSO's, protect health and reduce budget spends on flooding.

According to Preliminary Flood Risk Assessments (PFRA's) provided by Lead Local Flood Authorities (LLFAs) and Natural Resources Wales (NRW) there are 8 PFRA in Wales and 40% of properties at risk of surface flooding. The Indicative Flood Risk Assessment for Swansea in 2011 found surface water flooding in the most urbanised area of Swansea, with the consequences of flooding affecting 6962 population, equivalent to 2975 properties which has likely increased with changing climate and increased storms (Sweeney, 2011)

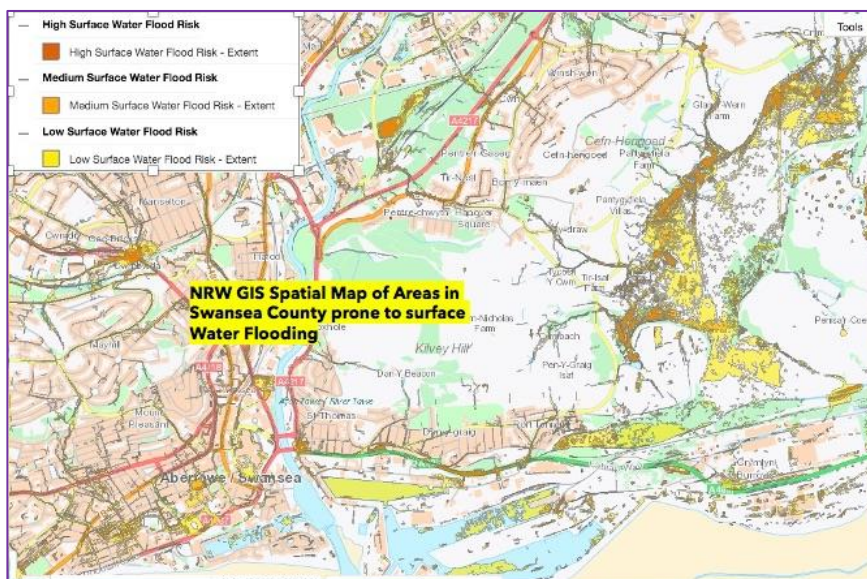


Figure 5 GIS map with NRW overlay Surface flooding

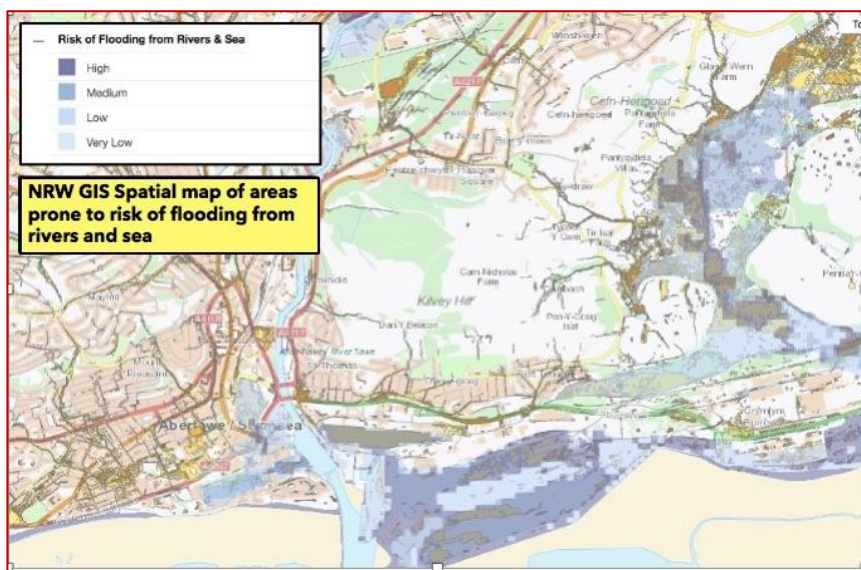


Figure 6 GIS map with NRW overlay river and sea flooding

Swansea has an ageing and expanding population which is likely to represent a significant increase in the demand for health and social care services and within Swansea county 1/3 of the workplace population are suffering mental health problems such as depression or anxiety (Swansea Council, 2020).

A report found there was an increase in reported levels of mental illness for more deprived areas - at 8% in the least deprived and rising steadily with deprivation to 20% in the most deprived (Mental Health Foundation, 2016), so ideas for regeneration focus on a green space increase within these areas in north Swansea which also show as more deprived on multiple deprivation index 2011(fig 7)

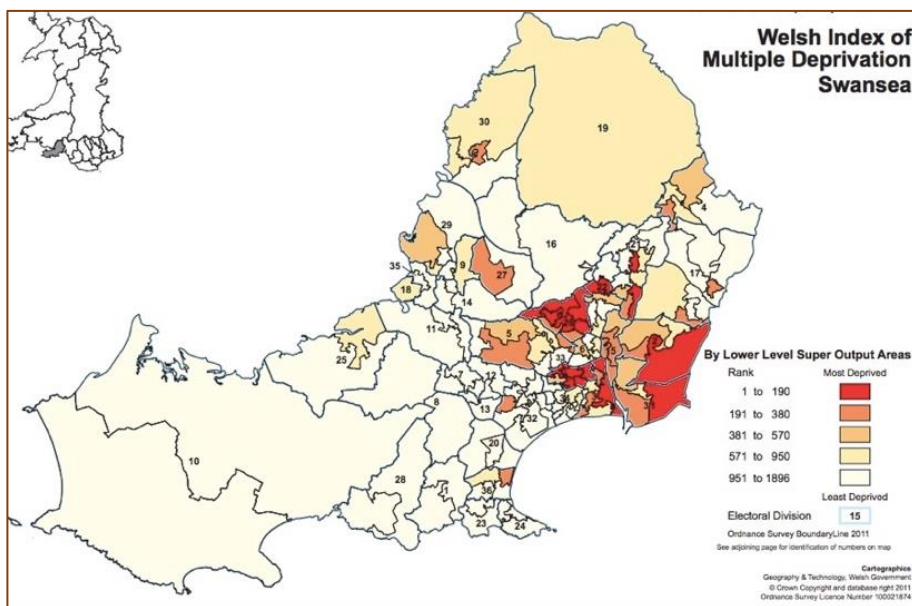


Figure 7 GIS multiple deprivation Map of Swansea County

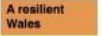
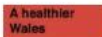
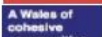
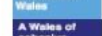
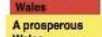
Swansea is rich with Biodiversity with a wide range of habitats including upland moorland, sandy beaches, coastal cliffs, heathland, woodland, wetlands, river valleys and estuaries. Nearly 70% of the habitats and 20% of species found within the county are classes are priority species for conservation and biodiversity in the UK. The natural environment makes up over 80% of the county with half being of ecological importance (Swansea Biodiversity Partnership, 2005; Gruffydd, 2019) Further SWOT shown below in (fig 8)

<u>Strengths</u> • Gower is UK's first AONB • Natural landscape / scenery and beaches around Swansea County • Extensive Variety of Habitats • Uniqueness of city, coast and countryside/close proximity to other key destinations with good transport links • 97% of respondents in the 2012 Visitor Survey said they would visit again • University City with good courses in Biology and Sustainable development available and conducting current research in conjunction with City Council. • Efforts being made with regards to Biodiversity - plan by council recently announced	<u>Weaknesses</u> • Growing, ageing population • Fragmentation of tourism community • lack of communication and integration between stakeholders • Lack of adequate car parking • 75% of commuters use a private vehicle, with just 16% using more sustainable forms of transport • Ozone objectives have not met compliance in Cwm Level Site and St Thomas sites • Lack of pedestrian access to city centre from SA1 development • Castle square lacks Biodiversity and engagement from communities • Lack of Green Roofs and SUDS • Poor drainage and porosity in SA1 Area - area prone to flooding • Poor engagement with South Swansea Sites such as Gower AONB by many younger generation North Swansea population - poor access? • Over 1/3 of the workplace population are experiencing mental health issues such as depression, stress or anxiety. • Poor Identity
<u>Opportunities</u> • Potential upcoming Tidal Lagoon project • Green prescriptions from NHS • Linking communities through Forest Gardens and collaborative practice. • Skill enhancement/ provision of learning sustainable practices to benefit wellbeing/air quality/flooding and biodiversity	<u>Threats</u> • Climate Change • Shoreline erosion/ encroachment - Shoreline Management plan • Growing Population growing need for resources • Greater burden on CSOs - Climate change • Co2 levels rising in atmosphere • Brexit

Figure 8 SWOT analysis

Regeneration Plan and Discussion 3.0

Table 1 Table showing overview of Proposal Plan

Proposal	What it entails	Aims	FWGA link
1. Green Infrastructure	Implementation of different Suds such as rain gardens, permeable paving, living walls, green roofs, green roofs on bus stops and Urban Street Canyons with focus on specific areas to address and target issues found.	Improve air quality in areas not meeting PM 2.5 and 10 targets and generally around city centre and county, improve water quality and reduce flooding where NRW GIS maps show risk. Provide solutions to fragmentation by providing better habitat networks thus improving biodiversity.	 
2. SkyGarden/ Pedestrian Skyway	Linking SAI development with the City centre through the construction of a Pedestrian skyway or bridge with different areas of	Connect important university/business hub with city centre, new digital area and council buildings green space development, for increased footfall to both developments and ease of access to north Swansea. Increase Wildlife corridors to aid biodiversity, aid pollinators through increased pollinator friendly plants and provide citizens new area to engage with nature. Additionally connect north and south Swansea communities through accessibility	 
3. Community Forest Garden	Initially hours will need to be dedicated to planning and engaging public and the forest garden itself, in mosaic form needs to accommodate full range of environmental educational needs to engage local schools with project. There will need to be community commitment to concept and involvement in its implementation but forest gardens are low upkeep so minimal effort will ensue after initial outlay.	Create space for community engagement and lifelong learning, utilize specific trees and vegetation to aid carbon sequestration in the area to aid reduction of PM levels and utilise species inline with local BAP. Contribute to local produce economy and timber. Engage with social groups and local NPO's towards communicating sustainability message. Wellbeing benefits and NHS green prescriptions.	   
4. Castle Square Regeneration	Arrange local competition to design creeping garden potentially in shape of welsh dragon for castle square utilising local sustainable materials and seeds, engage public with creation phase to encourage continued engagement. Wings on dragon to form cover from rain so the space can be used any weather. Add more trees to surrounding square green patches which can aid carbon sequestration - the types should fit into local area, such as Oak, Hawthorn, Elder, Field Maple, Holly, Yew, Hazel etc	Bring Culture and heritage to Castle Square and identity to Swansea. Bring more greenery to area as the square formerly looked before previous regenerations, and aid biodiversity and pollinators. Provide social space and community engagement with city centre.	 

Green Infrastructure 3.1

Green Infrastructure and Sustainable urban drainage help to

- Create Habitat for threatened wildlife
- Contributes towards Local Biodiversity Action Plans
- Improved Water Retention
- Improves Air Quality
- Reduces Carbon Emissions
- Reduces the Urban Heat Island effect (Gruffydd, 2019)

High quality multifunctional green infrastructure has the potential to deliver resilience, prosperity, nature, health, wellbeing and happiness to the citizens and visitors of Swansea.

Green Space Factor CAVAT should be considered- A tool for measuring quantity and function of green infrastructure proposed as part of planning applications (How, 2018); - useful in flood risk areas such as St Thomas and the north of Swansea

The addition of green roofs can benefit areas of high NO2 and ozone readings and as shown in (fig 9) the whole county can benefit from improvements in this area.

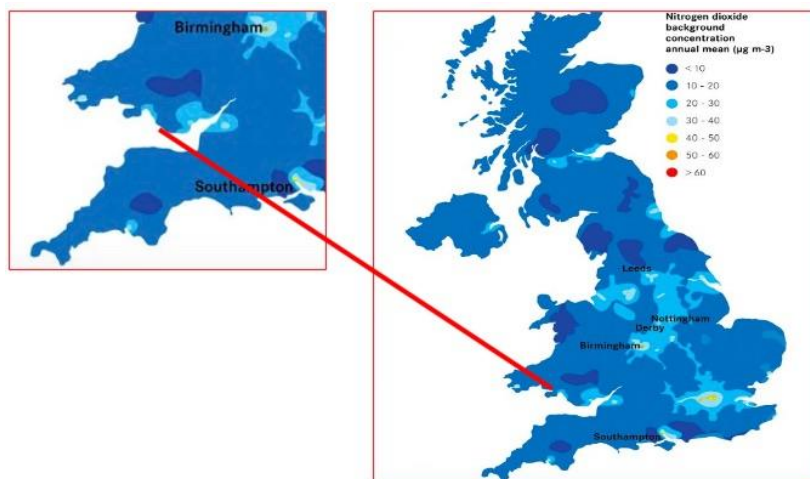


Figure 9 NO2 and ozone readings shown on map and close up of Swansea –

Green Roofs 3.1.1



Figure 10 Green roofs in Beirut - Sonuparlak, 2012

Green roofs provide benefits such as;

- the reduction and slowing of stormwater runoff and surface flooding
- reduced urban heat island effect
- removal of air particulates
- produce oxygen
- provide shade
- establishes landscape connectivity for pollinators and other species (Stovin, 2010)

The green roof code of practice provides guidelines for developers and public to make the transition with the most benefits and in line with required strategy/legislation. According to a study conducted by the National Research Council of Canada, even a six-inch extensive green roof can reduce summer energy demands by more than seventy five percent (Davis, 2015). A case study by Hammerle found that green roofs can have multiple positive ecological and physical effects, protecting the roof's waterproofing from current and future

external influences, and the combination of the vegetation and functional layering (fig 9) insulates the building against heat loss and creates energy savings from lesser need for air conditioning units (Oberndorfer *et al.*, 2007) .

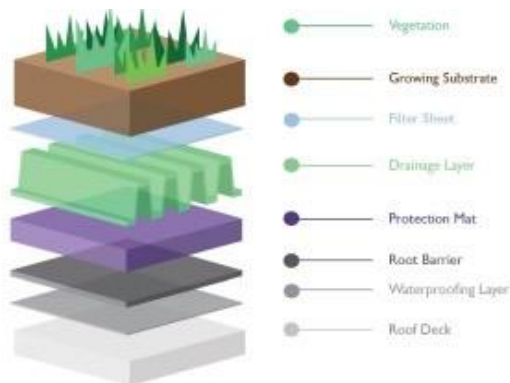


Figure 11 diagram of green roof layering - Growing Green Guide 2019

The most valuable benefit is the stormwater retention capability of green roofs which can provide potentially huge savings for the client and the community overall (Breuning, 2014).

Biodiversity wise the size, height, and design (e.g. substrate, planting, irrigation, and maintenance) all contribute to the types and numbers of species frequenting green roofs (Mayrand and Clergeau, 2018). The specific species suggested on the Swansea local biodiversity action plan should form the basis of habitat and species management. For highly mobile insect species such as bees and weevils, the number of green roofs within an area can increase their connectivity as a habitat type (Braaker *et al.* 2014) (Lepczyk *et al.*, 2017).

A case study in London found evergreens and seasonal plants as well as herbs, grapes and crab apples useful from a multiple perspective of encouraging well-being and biodiversity benefits as they encouraged insects, bees, moths, butterflies and birds and engagement in gardening (City of London, 2011) . A study considering carbon sequestration capabilities of green roofs found that green roofs both sequestered and offset carbon and found that Sedum aizoon was better for overall than other grass types tested but that overall the sequestration benefits were greater (Kuronuma *et al.*, 2018). The implementation of green roofs could be beneficial throughout the county but particularly in specified areas with poorer air quality such as St Thomas and CWM levels surroundings and areas with surface water flooding.

Rain Gardens 3.1.2



Figure 12 Rain Gardens - Urban Greenup 2018

Rain gardens are retrofit SuDS which can improve the quality and reduce the volume of surface water flowing to urban watercourses, helping diffuse urban pollution by maximising surface water interception, attenuation and infiltration. The implementation of these gardens around the specified areas suffering from surface flooding on (fig) could prove beneficial. A case study in Nottingham city centre looked at 21 linear rain gardens (total of 148m²) which were constructed within the grass verge, “utilising a combination of clean stone aggregate and proprietary units to create void space beneath a planted topsoil layer” and found a 33% reduction in the flow reaching the sewer during storm event (Campbell, 2015) and a case study on Greener Grange town in Cardiff found similarly that by adding 108 rain gardens and 130 trees this removed 40,000m³ of rainwater from the combined sewer networks and found benefits in mental health and general population well-being from engagement in nature, and increased green corridors for biodiversity (Susdrain, 2018)

Permeable Paving and Bio concrete 3.1.3



Figure 13 Permeable paving - Iarset, 2017

Permeable paving, a type of suds can be paving such as permeable asphalt, permeable concrete or concrete pavers. There have been benefits found in Discharge of storm water pollutant and Reduced temperature (Kale.S *et al.*, 2017)

A case study in the digs Bristol found that Form pave, a permeable paving by Aquaflow works by allowing runoff into a stone subbase which treats the runoff by filtration and microbial action before being slowly released in a controlled manner and at a low cost and improvements to surface water drainage in the local residential area helping ease demands on storm drains and provide accessibility for pedestrians (Campbell, 2015). Implemented in certain areas of North Swansea could provide drainage to areas prone to surface flooding as shown previously on GIS map.

Living Walls 3.1.4



Figure 14 Green Walls, Cecile Poignant 2017

Living walls can contribute significant environmental, social and economic benefits to the built environment and research found them a valuable part of the design process for addressing climate change and the energy crisis providing reductions in urban heat island effect, air quality and and benefits to energy conservation (Sheweka and Magdy, 2011)

The living wall could also function for urban agriculture or urban gardening . The addition of more living walls to buildings also falls in line with the tall buildings act suggesting inclusion of plants in the envelope of buildings for temperature control (Swansea Council, 2016).

A case study on Edgware road Lyons place in London found the implementation useful in areas with poor air quality. Edgware road is a busy London street with high levels of harmful pollutants. This study found A 150m² - 300m² living wall provided the equivalent of 7.5 medium sized trees being planted in terms of carbon sequestration. The wall with modular structure, includes 15 different species of plants covering an area of approximately 200 square metres shown in (fig 15) along with a diagram of bio wall modular system (fig 16) (Ansglobal, 2019)

An MSc student at Imperial College London reviewed the deposition of particulate matter to vegetation, finding that leaves which are waxy, hairy or deep veined are better at trapping particulate matter than smooth and supple leaves (Cheetham, 2012).



Figure 15 Green Wall planting design at Edgware rd – ANSglobal, 2019



Figure 16 Bio wall modular system – ANSglobal - 2019

For future living walls, Researchers at UPC have found a way to build structures with biological concrete (The Plaid Zebra, 2015) which allows biological organisms to grow on it, lowering CO₂ in the air but as of yet there were no case studies found to support this product which is newly trialling (Seifan, Samani and Berenjian, 2019)



Figure 17 Biological concrete virtual model – image by – C. poignant 2017

Green bus stops 3.1.5

The aim is to implement green roofs to bus stops throughout the city centre and additionally at strategic locations in the north Swansea to provide benefits to pollinators, air quality, visual wellbeing and engagement with nature for communities in line with FGWA

Green bus stops made up of mainly sedum plants were successfully implemented in Utrecht in Holland. A total of 316 bus stops were covered in greenery and the shelters support the city's biodiversity such as honeybees and bumblebees, and also help capture fine dust and store rainwater benefiting air/water quality and surface flooding (Giordano, 2019).

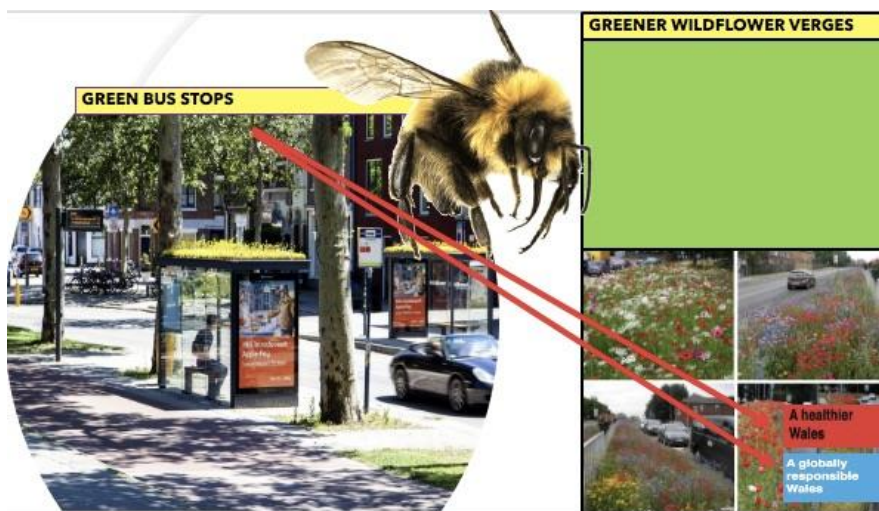


Figure 18 Green bus stops in Holland - Matsere, 2018

Skyway 3.2

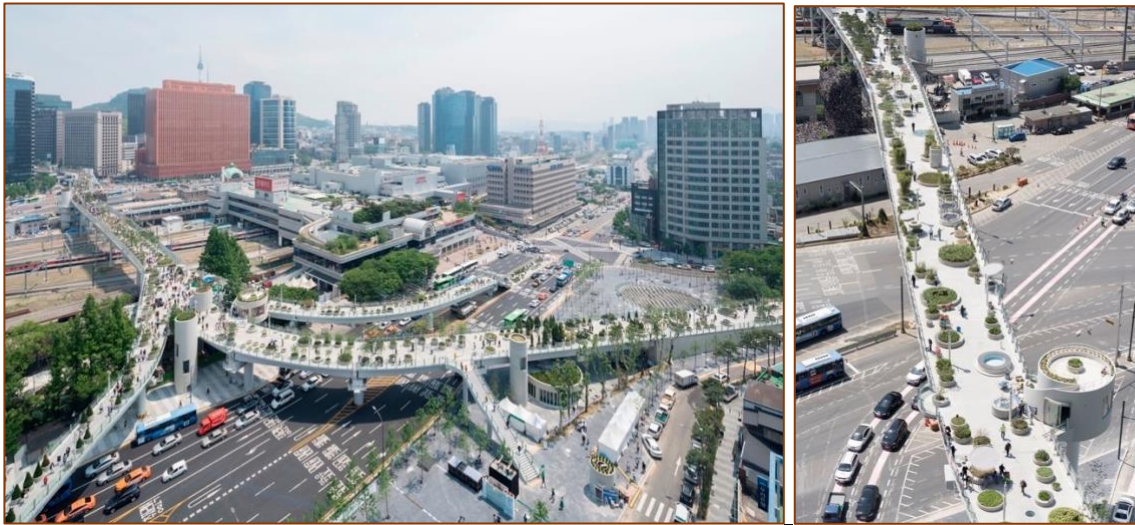


Figure 19 Seoul Sky garden - Archdaily - 2018

The second idea is to instate a sky garden/pedestrian skyway to connect SA1 with the city center and the new development starting on the civic center area. This could potentially connect wildlife corridors and communities between the north of Swansea sa1 which is currently quite cut off from the city center, this could provide a scenic vista over coastal and marine landscape and immediate benefits such as increased biodiversity and Wellbeing to ease high NHS mental health issues in Swansea. A case study in Belfast by Arup implemented Seven new steel bridges and two small-span wooden bridges which now act as connections between communities, linking a network of green spaces (ARUP, 2018). With the locality of a steel works and recycled steel, the construction could potentially be utilising recycled steel from Port Talbot saving carbon footprints and using local resources. Another option found from case study of a bridge Easter Dawyck Bridge, which is the longest plastic bridge in the world, made from recycled plastic. The bridge was built by recycling 50 tonnes of waste and can bare the weight of vehicles of up to 44 tonnes and is 100% recyclable. Plastic as a materia is light and stable, so does not corrode, rust or require regular treatment or maintenance does not rust, does not require painting nor any form of treatment of maintenance (Iberdrola, 2020)



Figure 20 The Easter Dawyck Bridge, the longest in the world built using recycled plastic. Photo: Sicut / Veritech LTD.

The addition of these pedestrian bridges in Scotland are facilitating sustainable travel and healthier lifestyles, and are reconnecting people and places, falling in line with the future well-being act; a healthier wale and a wales of more cohesive communities. The Seoul sky garden, having been made from an abandoned highway, found success and improvements in local air quality and population wellbeing (Valdes, 2018). New York also have a successful skyway called high line made from an old train track. Both have brought great economic benefits to the cities such as new businesses/ projects brought to the area, housing prices have gone up, and the NY highline has a curriculum for locals and children to learn more sustainable practices (ASLAF, 2018) which will help long term with environmental goals. This map shows potential location for the skyway but obviously more analysis into upcoming developments would be needed for precise location.



Figure 21 GIS map showing potential skyway location

Castle Square Regeneration 3.3



Figure 22 Figure 22 Castle square potential plan -image - Bob. M - 2018

The third idea endeavors to regenerate and iconize castle square and bring back the former biodiversity of previous years. This project would aim for community and NPO involvement with engagement with local cultural and art scenes, local artists and the public designated to design a creeping garden in the shape of the Welsh dragon, bringing a sense of identity to welsh people proud of their heritage and can bridge generation divides. The design would possibly in segments to avoid disrupting seating availability around the square, so appearing as one shape from above but infect, a series of separate shape. The design would include Wings from plastic bottles or recycled locally plastic to create cover from rain, enabling public to utilize the space in all weathers. Maintenance could be designated to some of the NPOs like WCADA which do day programs to help rehabilitation and mental health and help people gain skills and wellbeing, encouraging public engagement.

Creeping gardens and the addition of green space will bring great biodiversity benefits to this urban space if design and species mix is carefully considered and in line with local BAPs, thus helping aid carbon sequestration. The quantity of tall rising buildings around the square can potentially create urban street canyons, which are dense urban areas where pollutants can become trapped from the air recirculating between buildings. Considering London as a case study, the study modelled the effects of vegetation on the deposition and concentration of NO₂ and PM₁₀ in street canyons. At low wind speeds, the effect of vegetation on pollution was enhanced with reductions in air pollutant concentrations of as much as 40% and 60% for NO₂ and PM₁₀ (Pugh *et al.*, 2012). Substantial street-level air quality improvements could be gained through greenery placed strategically around single street canyons in the city centre, particularly round High Street and towards Hafod.

Community Forest Garden 3.4

The final proposal is to implement an edible community forest garden with visitor center, linking in with other community forest gardens located in surrounding areas which will bring many ecosystem services to the area. Agroforestry is defined as “the integration of woody vegetation, crops and/or livestock on the same area of land” (Björklund, Eksvård and Schaffer, 2019). Edible forest gardens with 500 edible plants only need a few hours a month maintenance after the initial set up period and can provide urban agriculture in a time when fresh produce due to potential import restrictions from Brexit are instable.

On a local scale urban forests have proven beneficial in levelling of climate, taking away extremes in temperature, water retention aiding run off, improved soil and air quality and soil carbon sequestration (Jose, 2012). Mixed deciduous forest can absorb up to 15 tons of particulate matter per hectare and coniferous trees are even more efficient with spruces absorbing double the amount. These agro-forests can also enhance community engagement, recreation and the possibility of skill learning which all promote the future well-being act principles such as resilient wales, a prosperous wales, a wales of cohesive communities and a healthier wales (Clark and Nicholas, 2013)

There are a number of other sites which have woodland volunteers such as kilvery hill and pennleagaer woods and also a community garden called vetch. The project community garden has not only enabled positive social interaction but has also promoted environmental awareness - and encouraged cultural understanding. The site has become a focal point for the community – a place for people of all ages and backgrounds to meet, talk and work together – sharing skills and knowledge, exchanging seeds and stories, and willing to lend a helping hand to neighbours (Sustainable Swansea, 2013). The community forest would link in with these other community patches from the initial creation phase hopefully utilising existing knowledge and best practices.

The location would be at the foot of st Thomas which could help with PM10 and pm.25 readings. Locating the forest garden here will also connect new developments in Hafod and the skyline in kilvey hill as well as encouraging nature engagement with already existing woodland and historic walks located between foxhole road – going up to white rock. Creating a community growing space may be a great way of bringing the different groups that use the Community Centre and members of the wider community together and Community Centre growing space could also be used for training sessions in ‘urban forest gardening’ and the skills learned here could be utilised across the community.

A study of 12 urban forest gardens in Sweden varying from home gardens to larger scale projects found that it was important to consider the species mix based on site characteristics. Each of the studies planned design and species composition to optimize these functions and benefits were nutritious and tasty food products, nitrogen fixation, nutrient accumulation, the provision of quality food for pollinators, carbon sequestration, contribution to a benign microclimate and the provision of timber (Björklund, Eksvård and Schaffer, 2019). Each of

the studies planned design and species composition to optimize these functions (Volkman, 2016). Suggestions for the garden would be a mix of sizes and species in line with local BAP and for their known ecosystem services. Trees such as English Oak (*Quercus robur*) and Field maple (*Acer campestre*) are large trees effective at storing carbon, long living natives such as Hazel (*Corylus avellana*), Blackthorn (*Prunus spinosa*), Goat willow (*Salix caprea*) and Crab apple (*Malus sylvestris*) are effective for smaller spaces and Elder (*Sambucus nigra*), Hawthorn (*Crataegus monogyna*), Holly (*Ilex aquifolium*) and Yew (*Taxus baccata*) are good carbon sequesters from the medium tree range (BBCNEWS, 2019). Primarily there should be consideration of species already successful on site or around a nearby site (Breyer, 2019) .

And also a mix of different edible plants and following guidance from agro-forest research trust food forests in a temperate climate should aim to have around seven layers: High trees, smaller trees, shrubs, perennials, groundcover layers, root crops, and climbers which helps with future resilience from different climatic events predicted (Association, 2019)



Figure 23 GIS map of potential community garden location - mapinfo

Conclusion 4.0

In conclusion the plan aims to;

- Improve Air Quality through the utilisation of ecosystem services such as Greens spaces, Living Walls and roofs
- Improve Water Quality/ Flooding – Green Infrastructure – SUDS – amount of rainfall and amount of runoff - rain gardens, permeable paving
- Mental wellbeing – Access to green spaces, pedestrian skyway, community garden
- Connecting People – Community Forest Garden, rain gardens
- Enhancing Culture – Castle Square regeneration
- Enhancing Biodiversity and wildlife corridors– Green Bus Stops (pollinators), SUDS, Skyway and all suggestions
- Enhancing Access/Connections - to green spaces and city centre from SA1 and between north and South Swansea and the new developments planned at Council buildings– Skyway, positioning of Community garden linking with nature walks up to Hafod and Kilvey hill

In conclusion each proposal links together holistically to connect existing green spaces and the north of Swansea and new proposed developments to hopefully bring more engagement with nature and connection amongst communities, through the implementation of greater green spaces, provision of skill learning, a greater awareness of sustainability and communities working together. In order to ensure a healthy and prosperous future wellbeing for the generations to come and the current generation, with safe and strong communities, and a balanced economy, it is essential that we utilise ecosystem services more exclusively and place rich biodiversity as a key indicator for health and wellbeing, the two must be cohesive.

Table 2 Table showing costing estimates

Proposal	Rough Estimates of Cost	Source of Estimate	Maintenance/Funds
GI - Green Roofs	Average cost per square meter of extensive green roof system is £50-100, whereas an intensive green roof system is £60-150	SedumSupply.co.uk	residents and bring in NPO's and offer lessons on vertical gardening - potential grants can be obtained for skill learning etc.
GI - Living Walls	Living Wall at Edgware road used clean air fund (CAF) budget, £1m was allocated for additional GI at PM10 priority locations.	London.gov.uk	Council and bring in NPO from area and offer lessons on vertical gardening - potential grants can be obtained for skill learning etc.
GI - Permeable Paving	The cost of permeable paving works out to be one of the most cost effective ways of renewing a surface, when you take into consideration the lengthy expected life span of the surface the cost per year is lower than alternative surfacing methods. The cost of Rio Permapave Textured Driveway Paviers is £546 per pack or £67 per sq meter	Tumbullsonline.co.uk	Personal maintenance by resident - council could provide skill learning classes to aid this transmission
GI - Rain Gardens	The project in Nottingham delivered 148m2 of rain garden which equated to £460 per m2. The cost for rain gardens filled with aggregate was around £300 per m2	Nottingham Case Study - Susdrain.org	Residents could create there own rain gardens and LA responsible for public rain gardens - can bring on volunteers for maintenance which should be minimal
Pedestrian Skyway	Pedestrian skyways can be highly expensive to build, a project in rayleigh in South Carolina found costs in excess of \$1 million dollars. Potentially by utilising either recycled plastic or steel this could lower costs but with the bridge being over water, this could make it unfeasible	Ced.sog.unc.edu - UNC School of Government	Developers would be needed for construction and potentially costs funding/grants raised from stakeholders that can potentially profit from increased footfall
Community Forest Garden	A study of a 5 yr forest garden utilised a £500 grant and only spent £12 for a greywater treatment system. Main funds spent on Trees and plants but these could also come from linking with the other local forest gardens in Swansea and sharing seeds etc.	Permaculture.org.uk	Community groups, organisations and schools either currently involved in, or wishing to develop growing spaces in their community can apply for a grant of between £250 and £5000 and potentially sell fresh produce or create jams as a small source of income for maintenance also heritage lottery fund has been used in Epping forest to build a visitor centre
Castle Square Regeneration	Varying costs including trees and new permeable paving - The cost of Rio Permapave Textured Driveway Paviers is £546 per pack or £67 per sq meter. Costs need further consideration	Democracy.cityoflondn.gov.uk	A project called Branching Out in Epping forest utilised heritage lottery funding to improve access to the landscape, and a new visitor centre and uses volunteers for continued maintenance

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