Develop a policy on sustainable urban drainage systems

1. EXECUTIVE SUMMARY

1.1. Surface water flooding is an increasing problem exacerbated by increased urbanisation, climate change and legacy poor drainage assessments in relation to both surface water and combined sewage infrastructure. Excess surface water in the sewerage system can lead to issues such as overflows and spills to the environment, as well as additional carbon emissions from pumping and treating surface water unnecessarily.

1.2. Excess surface water on the Isle of Man is largely managed through adapting conventional pipe based drainage systems to attenuate and restrict flow. Developers are required to ensure runoff post-development is at, or lower than, undeveloped greenfield runoff rates. Sustainable Drainage Systems (SUDS) are ways of managing surface water in a more holistic and sustainable manner. SUDS differ from conventional pipe based drainage solutions in that they do not only deal with issues of water quantity (flooding), they also take water quality (pollution), biodiversity (wildlife) and amenity (people) into account.

1.3. Due to this broader approach SUDS can also enable communities to cope better with the impact of climate change; for example: reducing and slowing surface water runoff, reducing the frequency and severity of flooding, greening and cooling the urban environment, storing water for reuse, and offering flexible infrastructure. SUDS can also help to mitigate climate change through carbon capture (sequestration) and by green infrastructure such as trees, green roofs, ponds and wetlands etc.

1.4. In order for the Isle of Man to gain maximum benefit from SUDS, it is recommended that a Government SUDS policy should be developed which may include the following principles:

- Surface water should be managed for maximum benefit;
- Surface water should be considered as a resource rather than a nuisance;
- Management of surface water should be equitable;
- SUDS should be considered at the earliest stages of site selection and design;
- SUDS should meet a minimum design standard;
- Planning policy should support SUDS policy;
- SUDS Hierarchy: vegetated SUDS should be promoted over non-vegetated SUDS, rainwater should be allowed to soak into the ground where possible, water should be controlled as close to source as possible.
- Surface water runoff should be managed above ground where possible;
- Development in existing urban area should be prioritised over green space development;
- SUDS should be sustainable in the long term;

- SUDS should be as safe as reasonably practicable.

1.5. The contribution of SUDS to carbon sequestration targets are likely to be small for both 'necessary' and 'high ambition' pathways (estimated as 0.1% and 0.24% of the Isle of Man total emissions budget for 2017 respectively), however the co-benefits of SUDS are significant. In addition to the water quantity, water quality, biodiversity and amenity, climate adaptation and mitigation SUDS can also contribute to health and wellbeing, recreation and education and bring benefits for developers.

1.6. In order to deliver a successful SUDS policy it will be necessary to establish an appropriately resourced adoption body (or bodies) with clear roles and responsibilities for developers, planners and those adopting and maintaining SUDS. The adoption body should set approval criteria and establish a process by which SUDS are adopted.

1.7. In the UK (with the exception of Scotland) SUDS have not been widely implemented due to a weak statutory position. The Isle of Man should avoid this situation developing by creating a robust legislative and planning framework for SUDS.

1.8. The design and construction guides *'Manx Sewers for Adoption'* (Drainage Division Department of Transport and Water Research Centre Plc., 2003), and *'Manual for Manx Roads'* (Department of Infrastructure, 2017) will need to be reviewed and updated to support SUDS policy and adoption.

1.9. The current Planning and Building Control regulatory frameworks should be reviewed to ensure that all the proposals align and maximise the benefit of the high level SUDS, i.e. requirements for effective catchment, wide surface water management and the development of new policy principles, where needed, or the expansion of those already in existence. A review of the Strategic Plan 2016 is proposed in 2020 as part of the Planning Action Plan which could include high level SUDS requirements.

1.10. To aid the delivery of water quality improvements through SUDS, water quality standards should be developed for receiving water bodies. For example the Isle of Man should consider adopting the water quality standards set out in the Water Framework Directive and SUDS should be designed to meet these standards.

1.11. To aid the delivery of biodiversity improvements SUDS should link with local biodiversity action plans where possible and access to any biodiversity funding should be made available to SUDS development where the biodiversity criteria can be shown to be met by SUDS.

1.12. Barriers to SUDS can include physical constraints of development sites, delays to planning, lack of community engagement, adoption and maintenance requirements, and health and safety concerns.

1.13. The costs (and returns) of SUDS will vary from site to site, however studies have shown that capital costs are typically on a par with, or lower than, conventional pipe based solutions. Maintenance costs are however, on average, higher than traditional solutions. There are a number of tools available to assess the whole life costs for SUDS schemes, such as SCOTSNET (2010) and B£ST (2019).

1.14. The development of a Manx SUDS policy supported by appropriately resourced planning, advisory and adoption bodies, is likely to bring multiple benefits to Manx communities, including improved flood risk management, climate change resilience, more visible and connected habitats as well as ecosystem services including carbon sequestration (see also WP5).

2. SURFACE WATER FLOODING

2.1. Surface water flooding is a growing problem, it happens when too much water arrives too quickly and there is nowhere for it to be discharged to—either by soaking into the ground, draining into a watercourse or built drainage system, such as surface water sewers and culverts (CIWEM, 2019).

2.2. Natural environments, such as wetlands, peatlands, bogs, marshes, forests, glens, open moorland and agricultural land all act to slow and capture rainfall; water is absorbed into the ground, fills up ponds, travels through soils and substrata filling up groundwater reserves, is taken up by vegetation, and is allowed to return to rivers and streams in a relatively control manner.

Urbanisation and reduced green space

2.3. Urbanisation reduces the amount of green space/ natural environments available to absorb rainfall and the increased amount of non-permeable surfaces accelerates runoff speeds for surface water resulting in an increased risk of flooding locally and also in downstream communities. Water quality problems also emerge as a result of urbanization as pollutants and excess nutrients wash off hard surfaces into receiving water bodies (Hatt *et al.,* 2004).

Climate change and increased storminess

2.4. Climate change and warmer air temperatures are driving more frequent and more extreme precipitation events, as warmer air is capable of holding more water vapour than cooler air. Recent research on climate change suggests that:

- winters may become milder and wetter with more intense rainfall events
- summers may be hotter and drier across the UK, with water availability in summer expected to decrease.
- extreme weather events may become more frequent, e.g. heat waves, cold snaps and heavy rainfall (Susdrain.org, 2019).

2.5. The dual stresses of increased urbanisation and climate change are increasing the pressures on drainage systems in urban areas resulting in more surface water flooding and unlike other sources of flooding, such as tidal, it can be less predictable and affect properties not identified on flood risk maps (CIWEM, 2019).

2.6. The 2017 UK Climate Change Risk Assessment predicts that annual flood damage to residential properties could rise by 22-78% in 2050s and 47-160% in 2080s (HM Government, 2017).

Inadequate urban infrastructure

2.7. Many Manx towns have substantial combined sewerage networks where surface water runoff and sewage are collected together. This Victorian infrastructure was designed to use the surface water to dilute the sewage waste before it flowed by gravity out to sea untreated. As most new developments are now being constructed on the periphery of existing town boundaries, it is common that the existing drainage infrastructure within the drainage catchments are inadequate to convey surface water flows. Now that most sewage on the Island is treated at either the central treatment works at Meary Veg or in regional sewage treatment works that additional surface water is a burden on the system. This additional flow causes problems, not just of overloading the sewerage systems above their design capacity leading to problems such as increased pipe failure rates, manhole overflows and spills to the environment through combined sewer overflows (CSOs) (Zhou, 2014), it also means that additional (clean) water is unnecessary pumped and treated adding to the carbon footprint of the sewage treatment process. Ofwat estimates that about half of average annual flooding incidents are a result of the capacity of the drainage system being exceeded (Gordon-Walker, Harle and Naismith, 2008).

2.8. Sewage base flows to Meary Veg are around 300L/s. During heavy downpour events flows can increase to around 700-1000L/s. Not all of this additional load would be treated though as Meary Veg has a maximum treatment capacity of 400L/s, so anything over this spills to sea in a very diluted form.

2.9. Potential carbon savings from reducing the amount of surface water entering the combined sewage system are roughly 300g CO_2 per 1000L of sewage treated, although this will be reduced under extreme storm events when spills occur (see Annex A).

3. CURRENT SURFACE WATER MANAGEMENT

SUDS and SuDS

3.1. There is a subtle terminology difference between Sustainable Urban Drainage Systems (SUDS) and Sustainable Drainage Systems (SuDS); SUDS generally referring to adaptations to traditional piped drainage systems that focus on water quantity and help alleviate the impacts of additional surface water flow; and SuDS, which refers more widely to green infrastructure for the control of surface water, as well as pipe based solutions, but which is focused on water quality, wildlife, amenity, as well as water quantity. Some literature uses both terms interchangeably; however this paper will keep the distinction.

Conventional piped systems

3.2. Conventional piped surface water systems can be adapted through a number of measures to help control surface water flooding, such as resizing sections of pipework, installation of attenuations systems (underground storage tanks), detention and retention ponds, restrictors to control discharge of flow.

3.3. The drawbacks of adapting to increased surface water in this way is that there can be restrictions on the capacity and flexibility of altering existing infrastructure in already space restricted urban environments. Costs of installation and maintenance of adaptations to infrastructure can also be expensive.

Isle of Man current practice

3.4. Currently Manx practice is that if a developer wants to build on undeveloped green space then the design must ensure that the runoff is at or below the same level as reference figures for an undeveloped green field i.e. 7 L/s/ha. Guidance notes on SUDS design are available but the design process is largely left to the developer, i.e. they are not guided towards specific SUDS or SUDS as long as the required discharge rate is attained. Manx Utilities will review developer proposals, bringing in expert help if needed and will also check onsite development is being built to specification. To meet the runoff requirements a developer will typically attenuate flows by building an underground storage tank for surface water with flow restriction that will control the flow of water into the surface water system. The storage tank will be spec'd to a 1:50yr storm event.

3.5. Where new developments are planned in built up areas that are already served by a combined drainage system developers are encouraged to investigate all economical options for the disposal of surface water to alternative disposal routes. If no feasible options exist they are requested to separate foul and surface water drainage and to install separate pipework to site boundary, ready in case opportunity arises for Manx Utilities to later install separate surface water and foul systems. In these cases attenuation of the surface water flows is still requested by Manx Utilities.

UK policy

3.6. England, Northern Ireland and Wales have yet to fully embrace SUDS technology in their planning policies and guidance, and hence SUDS are not widely implemented, whereas Scotland has developed policies which have enabled it to implement SUDS as a surface water management strategy for the last 15 years (Charlesworth, 2010). The UK has not issued full national standards to facilitate SUDS uptake, only brief non-statutory guidance has been published. Under current planning rules planning applications relating to major developments (10 or more dwellings, or equivalent non-residential development) should ensure SUDS are put in place, unless demonstrated to be inappropriate. Because of the weak legal and policy position many developers opt out of the SUDS requirement on the basis of practicability and affordability (CIWEM, 2019).

4. THE OPPORTUNITY

SUDS (water quality, quantity, biodiversity, amenity)

4.1. SUDS is an approach to managing surface water that takes account of water quantity (flooding), water quality (pollution) biodiversity (wildlife and plants) and amenity (people) (Susdrain, 2019).

4.2. Sustainable drainage is moving away from the traditional thinking of designing only to manage flood risk, where runoff is regarded as a nuisance, to a philosophy where surface water is a valuable resource and should be managed for maximum benefit (Susdrain.org, 2019).

4.3. SUDS mimic nature and typically manage rainfall close to where it falls. SUDS can be designed to transport (convey) surface water, slow runoff down (attenuate) before it enters watercourses, they provide areas to store water in natural contours and can be used to allow water to soak (infiltrate) into the ground or evaporated from surface water and lost or transpired from vegetation (known as evapotranspiration) (Susdrain.org, 2019).

Adaptation

4.4. As the climate changes, average global temperatures are expected to increase between 2.2 and 6.8^{o}C, and although the average precipitation per year may be slightly lower than it is now, the temporal distribution is expected to change in that summers become drier, winters wetter and storm events become more frequent and intense (Murphy *et al*. 2009). Because of their broader approach to managing surface water SUDS can play a vital role with helping communities cope better with the impacts of climate change, for example:

- Reducing/ attenuating runoff
- Reducing frequency and severity of flooding
- Greening and cooling the urban environment
- Water storage – available for reuse.
- Groundwater recharge
- Flexible infrastructure/climate change adaptation

Mitigation (Carbon capture)

4.5. Although the primary focus of research into SUDS in relation to climate change has been in their ability to support climate adaptation addressing issues such as flood risk, cooling and water availability, now the possibilities for mitigating climate change through carbon sequestration are also beginning to be understood.

4.6. An assessment of the carbon sequestration abilities of vegetated SUDS was undertaken by Warwick and Charlesworth in 2011; Table 1 shows the average sequestration rates for different SUDS.

Table 1: Carbon sequestration rates: Extract from Warwick and Charlesworth (2011)

SUDS Device	Average Carbon Sequestration Rate (kg C m-2 yr-1)
Trees	1.14
Green Roofs	0.375
Ponds and Wetlands	1
Turf	0.04
AVERAGE	0.64

5. THE ACTIONS —SUDS POLICY DEVELOPMENT

New policy principles

5.1. In order for the Isle of Man to gain the maximum benefit from SUDS (water quality, quantity, biodiversity, amenity, climate adaptation and mitigation) a Government SUDS policy should be developed which may include the following principles.

5.2. Surface water runoff should be managed for maximum benefit: - water quantity, water quality, amenity, biodiversity and carbon/climate change. I.e. SUDS not SUDS.

5.3. Surface water should be considered as a resource rather than a nuisance: - Options to utilise the benefits of surface water should be considered before discharge to sea/watercourse. This should not mean that direct discharge to sea/ watercourses can’t happen, just that an assessment that this is the most beneficial option should be undertaken before assuming direct discharge without SUDS is the best option.

5.4. Management of surface water runoff should be equitable: Downstream communities should not be disadvantaged by up catchment development. Runoff from development sites should be slowed and stored to mimic natural runoff rates and volumes. Run off from rainfall events that exceed site SUDS capacity should be managed on site (where possible) / conveyed to storage areas that minimise the risk of flooding to lower catchments.

5.5. SUDS should be considered at the earliest stages of site selection and design.

5.6. SUDS should not be an afterthought, and the argument that a site has already been designed and there is no space left to include SUDS should be discounted. Pre-application advice should be made available to developers via Planning Department. Early consideration of SUDS should inform site layout around the drainage requirements, rather than the other way round. Existing natural water attenuation systems should be preserved.

5.7. SUDS should meet a minimum design standard - Guidance is available from bodies such as CIRIA.

5.8. Planning policy should support SUDS policy.

5.9. SUDS Hierarchy: vegetated SUDS should be promoted over non-vegetated SUDS (benefits of evapotranspiration, carbon sequestration, cooling etc.).

5.10. SUDS Hierarchy: rainwater should be allowed to soak into the ground where possible (e.g. through vegetated areas or permeable surfaces).

5.11. SUDS Hierarchy: Water should be controlled as close to source as possible (as usually cheaper and easier and avoids passing on problems to lower catchment).

5.12. Surface water runoff should be managed above ground where possible

5.13. Management of water on the surface should be prioritised as it offers multiple benefits including early flood warning, water quality - as more easily inspected and any pollution incidents are more visible; more infiltration and improved community understanding and engagement.

5.14. Development in existing urban areas should be prioritised over green space development –development of previously developed land should be prioritised over release of greenfield land.

5.15. SUDS should be sustainable long term – Maintenance, ownership, replacement etc. should be considered at planning stage and clear agreement as to which body is going to be responsible for the management long-term. This may require a single central body taking ownership and acquiring statue responsibilities for all SUDS. This body would require resourcing accordingly.

5.16. SUDS should be designed with sufficient capacity and/or be sufficiently adaptable to cope with climate change pressures and an increased level of urbanisation in the upper catchment. SUDS should be designed to manage runoff for both frequent and extreme rainfall events.

5.17. SUDS should be as safe as reasonably practicable for those living nearby, visiting or involved in their operation or maintenance.

New policy details: Surface water runoff should be managed for maximum benefit

5.18. **Water quality –** Water quality standards should be developed for receiving water bodies, for example the Isle of Man should consider adopting the water quality standards set out in the Water Framework Directive and SUDS should be designed to meet these standards.

5.19. **Amenity –** SUDS should provide additional amenity value wherever possible, e.g. open space for community inclusion and interaction, recreational areas for walking, cycling etc., enhancement of an area's visual character.

5.20. **Biodiversity –** SUDS should aim to support and protect habitats and species that are similar to/ linked with the natural existing surrounding habitat of the SUDS. (e.g. don't design SUDS to support woodland if the surrounding habitat is marshland. Consider what ecological communities might naturally thrive in the locality under the conditions expected). SUDS should link with local biodiversity action plans where possible and access to any biodiversity funding should be made available to SUDS development where the biodiversity criteria can be shown to be met by the SUDS. Flowers should be encouraged in SUDS grassland areas (e.g. wildflower meadow grass mix) to provide nectar sources. As SUDS are designed to manage water grass areas should also use turfs that can withstand waterlogging. Allow for natural colonisation by plants and animals.

Use surface water runoff as a resource

5.21. Rainfall is a precious resource and is likely to become scarcer in summer months. Capturing rainfall close to source for reuse such as gardens and allotments, car washing and toilet flushing can help alleviate summer water scarcity pressures as well as runoff into lower catchments.

Management of surface water runoff should be equitable

5.22. Downstream communities should not be disadvantaged by up catchment development. Runoff should be slowed and stored to mimic natural runoff rates and volumes.

5.23. Run off from new developments should be attenuated to levels that are at or below reference figures for undeveloped land (e.g. 7 L/s/ha for grass land).

5.24. The destination for surface water runoff that is not collected for use should be prioritised in the following order:

- Infiltration;
- Discharge to watercourses (including the sea);
- Discharge to a surface water sewer, highway drain or another drainage system;
- Discharge to a combined sewer.

5.25. Discharge to a foul sewer should not be considered as a possible option. As much of the runoff as possible (subject to technical or cost constraints) should be discharged to each destination before a lower priority destination is considered.

5.26. Where runoff is to be discharged to a surface water sewer or combined sewer Manx Utilities, as the sewerage undertaker, should be consulted as to whether any additional criteria or limiting discharge rates are required. Where runoff is to be discharged to a watercourse, Manx Utilities' Flood Risk Management department and DEFA's Environmental Protection Unit should be consulted.

5.27. Where runoff is to be discharged to highway drainage systems the Department of Infrastructure (DOI) should be consulted at a very early stage, as per the Manual for Manx Roads.

5.28. Where surface water is to be discharged un-attenuated directly to an adjacent watercourse, (depending on its proximity to the sea) the receiving watercourse will need to be assessed to determine whether the peak flows arriving from the upstream catchment will impact on any restricted surface water discharge from the development.

5.29. Run off from rainfall events that exceed site SUDS capacity should be managed on site (where possible) / conveyed to storage areas that minimise the risk of flooding to lower catchments

SUDS should be considered at the earliest stages of site selection and design.

5.30. SUDS should not be an afterthought, and the argument that a site has already been designed and there is no space left to include SUDS should be discounted.

5.31. Pre-application advice should be made available to developers via Planning Department.

5.32. Early consideration of SUDS should inform site layout around the drainage requirements, rather than the other way round.

5.33. Sites containing existing natural water attenuation systems such as wetlands, peatlands, streams, ditches etc. should be preserved wherever possible.

SUDS should meet a minimum design standard

5.34. SUDS should be designed so that runoff is contained within the site's drainage system for all events with a return period of 1:50 or less.

5.35. Properties should be fully protected against flooding from SUDS for rainfall events with a return period of 1:100 or less. (In Scotland a 1:200 standard is required – the Isle of Man should consider if this is suitable or whether a more stringent criteria should be set given the pace of climate change already observed).

5.36. Planning should set surface water management objectives for catchment areas e.g.

- Flood risk management objectives
- Water quality management objectives
- Community and amenity objectives
- Ecosystem objectives
- Maintenance standards
- Climate change requirements.

5.37. Annex B shows example SUDS design criteria that could be developed further.

Planning policy should support SUDS policy

5.38. Site developers should hold pre-application discussions with DEFA's Planning Department, Manx Utilities and the DOI, where applicable, to agree expectations for SUDS.

5.39. The current planning and building control regulatory frameworks should be reviewed to ensure that all the proposals align and maximise the benefit of the high level SUDS requirements for effective catchment wide surface water management and develop new policy principles where needed or expand on those already in existence.

5.40. A review of the Strategic Plan (2016) is proposed in 2020 as part of the Planning Action Plan which could include high level SUDS requirements.

5.41. Wider stakeholder engagement, e.g. local authorities, wildlife groups, community groups, should be a developer requirement, stipulated by planning policy.

SUDS Hierarchy – Vegetated SUDS should be promoted over non-vegetated SUDS

5.42. Benefits of evapotranspiration, carbon sequestration, cooling etc.

SUDS Hierarchy – Rainwater should be allowed to soak into the ground where possible

5.43. (e.g. through vegetated areas or permeable surfaces) – Subject to infiltration test and known localised problems.

SUDS hierarchy – Water should be controlled as close to source as possible

5.44. As it is usually cheaper and easier and avoids passing on problems to lower catchment. Where practicable, treatment systems should be designed to be close to the source of runoff as it is easier to design effective treatment when the flow rate and pollutant loadings are relatively low. The treatment provided can be proportionate to the pollutant loadings, i.e. parts of the site with low pollutant loads do not need to have as much treatment as highly polluting parts of the site.

SUDS hierarchy – Surface water runoff should be managed above ground where possible

5.45. SUDS offer a robust approach to managing rainfall events that exceed design conditions - rainfall more severe than allowed for in the system design. In surface based systems, water levels rise gradually and visibly during large rainfall events. With SUDS excess runoff can be readily conveyed from within the drainage system into defined safe exceedance conveyance pathways and storage zones. This enables communities to understand and prepare for flooding more effectively than when served by subsurface systems, where flooding can occur suddenly, when the design capacity is exceeded.

5.46. Further advantages of above ground SUDS include:

- Where sediments are exposed to UV light, photolysis and volatilisation processes can act to breakdown contaminants - specifically oils and other hydrocarbons.
- If sediment is trapped in accessible parts of the SUDS, it can be removed easily as part of routine landscape maintenance work.
- It enables use of evapotranspiration and some infiltration to the ground to reduce runoff volumes and associated total contaminant loads (i.e. interception), provided that the risk to groundwater is managed appropriately.
- Sources of pollution can be easily identified.
- Community engagement; above ground SUDS promote community awareness of how SUDS work and the benefits they bring. They are then more likely to act to protect its long-term functionality.

Development in existing urban areas should be prioritised over green space development

5.47. Retrofitting SUDS is a vital part of the overall strategy for making towns and cities more resilient to future climate change and urbanisation, considering new development only comprises around 1% of land use change within urban areas each year (Adaptation Sub-Committee, 2012). While SUDS for new developments (and redevelopments) can prevent any increase in flood risk from surface water caused by the development, retrofit SUDS can reduce the existing risk (Woods Ballard, *et al.,* 2015).

SUDS should be sustainable long term

5.48. Maintenance, ownership, replacement etc. should be considered at planning stage and clear agreement as to which body is going to be responsible for the management long-term. This may require a single central body taking ownership and acquiring statue responsibilities for all SUDS. This body would require resourcing accordingly.

5.49. The adoption body should set approval criteria and establish a process by which SUDS are adopted. The likely level of maintenance should be established in advance and costed accordingly. Where SUDS are proposed in public open space and also form an amenity function it may be possible to reach a shared maintenance agreement with the local authority.

5.50. SUDS should be designed with sufficient capacity and/or be sufficiently adaptable to cope with climate change pressures and an increased level of urbanisation in the upper catchment.

- SUDS should be designed to manage frequent rainfall events and extreme rainfall events:

Volume control for frequent rainfall events

5.51. SUDS should be designed so that runoff from the site to receiving surface waters does not occur for the majority of small rainfall events. E.g. mimic the hydraulic response from undeveloped land. Interception of rainwater can be achieved using methods such as rainwater harvesting, infiltration and evapotranspiration. This is particularly important for protecting water quality as pollutants flushed from surfaces are more concentrated in smaller rainfall events.

Volume control for extreme rainfall events

5.52. SUDS should be designed so that the volume of runoff discharged from the site during extreme events, e.g. 1: 100 year event, is controlled. The additional runoff volume should not exceed 2l/s/ha.

SUDS should be as safe as reasonably practicable for those living nearby, visiting or involved in their operation or maintenance.

5.53. SUDS should be no more hazardous than natural ponds and wetlands, puddles and surface runoff flows on roads, or in streams and rivers. Where runoff is likely to be contaminated and unsafe for human exposure, it should be kept within systems that do not encourage contact.

Policy pathways (necessary and high ambition)

5.54. As outlined in the previous sections, the benefits of SUDS are multiple, though the benefits specifically for carbon capture are yet to be studied to the same extent. There are however a number of opportunities for SUDS to contribute to carbon sequestration targets.

Housing policy

5.55. Isle of Man Housing Policy states that to meet the housing needs of the Island 5,100 additional dwellings will need to be built over the period 2011 – 2026.

5.56. A recently approved housing development in the south of the Island incorporated 282 houses in a site roughly 17 hectares, giving a housing density of 16.5 dwellings per hectare – much lower that the UK average of 32 residential dwellings per hectare for 2015/16. In the UK the expectation is that SUDS will be at least 10% of the total site area. The land take required to meet the Isle of Man Housing Policy, assuming a housing density of 16.5 dwellings per hectare, is 309 hectares.

Green roofs

5.57. The United Kingdom, as at 2014, had an estimated 3,700,000 m2 of green roofs with an estimated additional 250,000 m2 of new green roofs each year (EFB, 2015).

5.58. Unused roof space can represent up to 50% of the impermeable surfaces of cities (Mentens *et al.*, 2006).

5.59. There are very few studies of green roofs estimating their carbon sequestration capabilities, but the City of Los Angeles Environmental Affairs Department (LA EAD 2006) quotes an area of prairie grass that sequestered 700 tonnes of carbon in 2000; however, the numerical area was not given. Getter and Rowe (2009) report a study in which they assess the carbon sequestration ability of extensive green roofs over 2 years of monitoring. They admit that green roofs have often been studied from their energy saving and heat island mitigation abilities, but rarely in their climate change mitigation role. They calculate that if the city of Detroit, United States, greened its approximate 15 000 hectares of rooftop, then potentially 55 252 tonnes of carbon could be sequestered. Calculations of the estimated area available for green roofs in meeting the Isle of Man Government housing policy are available in Appendix D (Eunomia, 2019).

Car parks

5.60. In the UK, the high proportion of urban green space in some cities is now threatened by a relatively new phenomenon—the growing trend of paving over domestic gardens. Several reasons including increased car ownership, difficulty of on street parking, poor public transport and a fashion for low maintenance minimalist gardens have been identified as the likely causes (London Assembly Environment Committee, 2005).

5.61. A study by Perry and Nawaz (Perry and Nawaz, 2008) found that (in the given suburban study area) the amount of paved garden area increased 138% between 1971 and 2004 accounting for 75% of the total increase in impervious surfaces. The remaining 25% of the increase is due to increases in the 'buildings' and 'other impervious' categories.

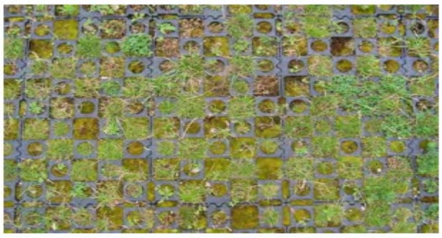
5.62. Assuming the trend for paving over garden areas is similar in the Isle of Man as it is in the UK then 114,810 m2 is available for pervious paving if the Isle of Man adopted a policy of only allowing front gardens to be converted to car parking if pervious paving was mandated. See Appendix C.

Table 2: Changes in impervious area for the study area

	1971	2004	% Change
Paved garden area	0.08 km2	0.19 km2	138
Average paved garden size	39.4 m2	53.4 m2	36
Number of properties with paved front gardens	2130 (71%)	2700 (90%)	19

A. Examples of types of block pavers used in permeable paving systems

B. Concrete-supported vegetated PPS



C. Vegetated PPS supported by plastic grids

Table 3: Identification of suitable locations for SUDS

Possible new SUDs locations	Area available
New housing developments (in meeting expected housing requirements to 2026)	309 Hectares
Green Roofs (in meeting expected housing requirements to 2026)	74.39 Hectares
Front gardens to driveways.	114,810 m2

5.63. Table 4 shows the potential carbon sequestration opportunities from adopting new policy in each of the three areas explored above—(SUDS in new housing developments, green roofs in new developments, and permeable driveways). The contribution of SUDS to carbon sequestration targets are likely to be small for both "necessary" and "high ambition" pathways - estimated as 0.1% and 0.24% of the Isle of Man's total CO_2 emissions budget for 2017 respectively.

Table 4: Carbon Sequestration Potential of new policy

SUBS Type	Pathway A (necessary ambitions)	Pathway B (high ambition)	Area available (ha)	Carbon sequest. potential; Pathway A	Carbon sequest. potential; Pathway B
New housing developments	10% of area available for SUDS	25% of area available for SUDS	309	10% of 309ha = 309,000m^2 x 0.64 =197,760 kg C yr-1	25% of 309ha = 772,500m^2 x 0.64 =494,000 kg C yr-1
Green Roofs	10% of area available for green roofs in meeting expected housing requirements	25% of area available for green roofs	74.39	10% of 74.39 Ha =74,390m^2 x 0.375 = 27,896 Kg C yr-1	25% of 74.39 ha = 185,975m^2 x 0.375 = 69,740 Kg C yr-1
Driveways. (Based on existing housing stock)	50% of expected land-use change from garden to driveway as permeable paving	75%	114,810 m^2	50% of 114,810 =57,405 m^2 x 0.04 = 2,296 Kg C yr-1	75% of 114,810 = 86,107.5 m^2 x 0.04 = 3,444 Kg C yr-1
Total potential Carbon savings per year				227,952 Kg C yr-1	567,184 Kg C yr-1
Total potential CO_2 savings per year (Carbon sequestration converted to CO_2 at a rate				835,229 Kg CO_2 =835.229 Tonnes CO_2 per year	2,079,674 Kg CO_2 =2079.674 Tonnes CO_2 per year

of 12.011g C =44.009g CO_2)					
As % of Isle of Man 2017 carbon budget: 0.839 MT CO_2				=0.1%	=0.25%

Table 5: Carbon sequestration rates: from Warwick and Charlesworth, 2011.

SUDS device	Average Carbon Sequestration rate (kg C m-2 yr-1)
Trees	1.14
Green roof	0.375
Ponds and wetlands	1
Turf	0.04
AVERAGE	0.64

6. THE CO-BENEFITS

6.1. The overarching principal of SUDS design is that it delivers multiple benefits.

6.2. As well as the benefits to water quantity, water quality, biodiversity and amenity, climate adaptation and mitigation SUDS can also contribute to:

6.3. Reducing pressure on conventional drainage systems, reducing combined sewer overflows and additional costs.

6.4. Enabling development (creating headroom for growth)

6.5. Water availability

6.6. Health and wellbeing, recreation & education

6.7. Carbon savings

6.8. Developer benefits

Water availability

6.9. Water availability in the summer is expected to decrease, the consequences of which are likely to be exacerbated by higher temperatures. For example, lower flows in rivers in the summer months would lead to reduced dilution of pollutants in runoff when summer rainfall events do occur. There may also be more frequent algal blooms and eutrophication. At the same time, population growth and higher summer temperatures are likely to lead to greater demand for water. The competing pressures of maintaining public water supply without causing environmental damage need to be managed sustainably. SUDS can help by supplementing water supplies through rainwater harvesting and reducing pollutant discharges into receiving waters (Woods Ballard, *et al.,* 2015).

Health and wellbeing, recreation & education

6.10. Although not a significant problem on the Isle of Man, SUDS in various forms have been shown to help provide urban cooling. They can make a significant contribution to supporting urban communities; people are more likely to feel that they belong to the local community and take a greater pride in their neighbourhood where they have opportunities for human interaction, such as recreational facilities and places to congregate (Woods Ballard, *et al.*, 2015).

6.11. Connected green infrastructure can facilitate walking and cycling routes within tranquil settings and recreational green space. SUDS can also be designed to provide opportunities for play and education, as well as communicating their purpose and how they work (Woods Ballard, *et al.*, 2015).

Carbon savings

6.12. SUDS can also help to reduce the embodied and operational carbon in drainage systems for example through reduce use of pumping and treatment. As noted earlier in this report potential carbon savings from reducing the amount of surface water entering the combined sewage system are roughly 300g CO_2 per 1000L of sewage treated (see Annex A).

Developer benefits

6.13. Speeds up the approval process – embracing a well-designed SUDS scheme encourages a faster approval process and facilitates positive planning outcomes.

6.14. Saves on Capital costs – a Cambridge housing development was reported to be 11% cheaper to construct than a comparable traditionally drained site, and another development in Leicestershire was reported to be 16% cheaper.

6.15. Makes development more attractive – SUDS enrich the aesthetic and recreational value of a development, promote health and well-being and support green infrastructure. Ultimately, making it a more attractive and desirable place to live, work and play. Land values and house prices located next to high quality SUDS components, incorporating well maintained open space such as ponds, swales and basins typically attract as much as a 10% premium on the selling price.

6.16. Can reduce the costs of maintenance – integrating SUDS into the site not only ensure the best use of space but could potentially reduce the costs of maintenance. For example; costs to sustain the SUDS scheme in Lamb Drive, in Cambridge were £38/per property, per year – 4% cheaper than the average equivalent for a traditionally drained system.

7. BARRIERS/RISKS

Physical constraints

7.1. "The Big SUDS Survey" carried out in 2016 by CIWEM (Charter Institution of Water and Environmental Management) found that site constraints, including both a perception of land take and physical constraints such as ground conditions, was the most commonly cited reason for not implementing SUDS in planning applications.

7.2. There are however many examples of SUDS being integrated within the footprint of developments for example through pervious pavements, tree pits, vegetated components, green roofs and rainwater storage (Woods Ballard, *et al.*, 2015) and a review by the Committee on Climate Change suggests that space for SUDS can usually be accommodated within existing open space requirements resulting in no additional land take (Royal Haskoning, 2012).

7.3. Unsuitable soil substrates for infiltration of water, such as clay soils, need not preclude the use of SUDS on site as all SUDS can be designed to attenuate (hold back water) as well as infiltrate (CIWEM, 2019).

7.4. SUDS can even be used on contaminated sites for example with lined attenuation such as Queen Mary's walk in Llanelli which is built with an impermeable membrane under it that achieves an 80% reduction in runoff to the sewer by evaporation (CIWEM, 2019).

7.5. Sites within urban areas are often confined and restricted. Planning and design constraints are often tighter than at other sites, and land is often more valuable. Introducing SUDS can appear challenging when faced with competing development objectives, but SUDS can be integrated into a development without negatively impacting upon the primary function of the urban space.

7.6. Working within the constraints of 50 dwellings per hectare, the development at Hunter Avenue incorporates green space effectively, improving the aesthetics and providing opportunities for recreation, while increasing the number of street trees on the site.

7.7. Permeable paving with below-ground attenuation is used to manage surface water runoff.

7.8. Exceedance flows are contained within the road curtilage and parking areas along the southern boundary of the site (Woods Ballard, *et al.*, 2015).

Delays to planning

7.9. CIWEM's "Big SUDS Survey" did not identify delays to planning as a barrier to SUDS development, rather CIWEM suggests that where delays do occur they are primarily the result of uncertainty over the adoption and maintenance of the systems rather than the construction of the SUDS themselves (CIWEM, 2019). It is important therefore that the issue of adoption and maintenance is clearly addressed in the new policy.

Community engagement

7.10. It is essential that new owners are informed that their property is drained by SUDS, and how the drainage works. Potential issues of community concern, particularly around subjects such as safety or parking, are likely to be identified earlier in the process, thereby increasing the likelihood of a viable and acceptable scheme. Consideration should be given to educating school children on the role of SUDS – e.g. interactive models.

Adoption and maintenance

7.11. One barrier to SUDS is their adoption and maintenance requirements. The maintenance requirements of SUDS should be clearly set out by designers during the planning stage and SUDS should be designed to facilitate ease of access and maintenance. To facilitate adoption of SUDS the designer/developer should provide an operation and maintenance manual to those who are later likely to have some involvement with the installations (owner, tenant, local authority, Manx Utilities etc.). This could be part of the documentation provided under CDM (part of the H&S file).

7.12. At the planning stage, a clear agreement as to which body is going to be responsible for the management long-term should be established. This may require a single central body taking ownership and acquiring statue responsibilities for all SUDS. This body would require resourcing accordingly. Any adoption body should be able to set approval criteria and establish a process by which SUDS are adopted. Appropriate legal agreements between adoption and maintenance organisations will need to be agreed between parties. Maintenance plans should be a requirement as part of planning permission for sites.

7.13. Any adoption body will also be hesitant to accept responsibility for the maintenance of SUDS without a clear indication of the expected costs for doing so. The likely level of maintenance and associated costs should be mapped out in the design stage.

7.14. Maintenance costs may need to include occasional and remedial maintenance costs as well as those associated with regular maintenance. Although not all systems will require remedial maintenance, for the purposes of estimating whole life costs, a contingency sum of 15-20% in addition to the annual regular and occasional maintenance costs to cover the risk of remedial maintenance works being required (as recommended by Woods Ballard, *et al.*, 2015). One payment mechanism to meet the operational and maintenance costs could be for the developers to pay a commuted sum to the adoption body. Where SUDS are proposed in public open space and also form an amenity function it may be possible to reach a shared maintenance agreement with the local authority.

Health and safety

7.15. Designers of SUDS have a responsibility to address health and safety under CDM regulations. A risk assessment should also be undertaken by the organisation approving the drainage when assessing the design of a SUDS scheme and further revisited at construction inspection and adoption approval stages. SUDS risks should also be monitored and reviewed as part of the site maintenance procedures. An example risk assessment matrix is shown in Appendix E.

7.16. Well-designed SUDS components should be no more hazardous than those found in the existing landscape such as ponds in parks. However there can still be a hurdle of overcoming public perception of risk. Society is broadly tolerant of the risks associated with the road network because of the benefit and support it brings to our daily lifestyle, if SUDS components that carry a risk are perceived as bringing an overall benefit to the local community then risks can be accepted. Public education and good design and maintenance are crucial in managing and addressing perceived risks (Woods Ballard, *et al.,* 2015).

7.17. Education strategies should cover:

7.18. The functionality of the surface water management system - where the water flows, where and why it is stored, where it is released to, what would happen if it wasn't there, how it will operate and how it is likely to look in different seasons.

7.19. The benefits afforded to the local community and wider society by SUDS scheme, including children's education opportunities.

7.20. The design measures in place to mitigate health and safety risks.

7.21. How and when the system is maintained.

7.22. The actions that the local community and amenity users should take to further minimise health and safety risks (including effective litter control).

7.23. Contact information if a health and safety or maintenance concern is identified.

7.24. Good SUDS design should reduce the risks to acceptable levels by designing out hazards.

7.25. Drowning is probably the biggest concern community users have around SUDS but risks can be reduced through a number of control methods (Woods Ballard, *et al.,* 2015):

7.26. Steep banks, areas of fast flowing water and areas that become inundated very quickly should be avoided in the design stage. Bodies of water near housing should have water depths limited to 600mm and velocities of less than 0.5m/s. The maximum water velocity in open water SUDS should be low enough so that if anyone inadvertently enters the water's edge they can remain standing.

7.27. It is not reasonable, practical or desirable to deny all access to bodies of water through barriers such as fencing – and fencing is often objected to by designers, health and safety experts and local communities themselves. Only at high risks sites should fencing be considered. Where it is considered likely that unsupervised young children could gain access to the water then low vertical fencing that restricts toddlers from getting into the water but which allows adults to step across when necessary should be installed. Where fences are provided, full responsibility for maintenance must be established to ensure that liability risks are minimised. At lower risk sites other barriers such as vegetation may be considered to deter access.

7.28. The siting of SUDS, for example with footpaths and houses overlooking can provide a high degree of natural surveillance from surrounding properties and residents.

7.29. Risks from water edges can be minimised by designing a dry level surface to act as a safe space from which to observe and assess the water. These can also be designed with a slight reverse slope away from the water to minimise the risk of accidental slipping into the water. All slopes should be no greater than 1:3 to allow able-bodied visitors easy of movement or maintenance personnel to mow and clear vegetation. A level area just below the normal water level which is wet and uncomfortable underfoot can also act as a safe deterrent for anyone in the water.

7.30. The water's edge should be clearly identified, e.g. through planting or hard edging (where appropriate).

7.31. Access to water can also be discouraged by shallow muddy margins and reeds and shrubs that don't obstruct visibility, but which provide a safe deterrent and barrier to paddling and swimming.

7.32. Life-saving equipment such as life rings have often been provided unnecessarily in the past and should only be provided if water conditions and location suggest there is a need e.g. deep water.

7.33. Other risks associated with SUDS include health risks from unclean water but these should be no greater than from water in recreational ponds in parks. Blue-green algae tends to appear in warm water bodies with high nutrient levels. SUDS should not be stagnant, but have low nutrient levels and be relatively clean. The risk of contaminated, stagnant water occurring in well-designed SUDS is very low, and the subsequent risk of a resultant adverse health issue is even lower. Those most likely to be at risk are maintenance staff and safe systems of work should be employed to mitigate risks. Employees who work near water should also be provided with a leptospirosis card that can be presented to medical professionals should symptoms of ill health appear.

7.34. Any water that is designed to be used by children as part of play features should be treated.

7.35. Signs educating users about health and safety risks should be displayed in accessible areas.

8. COSTS (AND RETURNS)

8.1. The costs and benefits of SUDS will be site specific and will vary significantly (in monetary terms) depending on the site characteristics, the use(s) of the site and the specific composition of the SUDS scheme. The two main cost components can be broken down as capital expenditure to build the SUDS, including potential land take costs, and the on-going operational costs to maintain them and ensure continued performance.

Capital costs

8.2. A number of studies have looked at the capital costs for SUDS and summaries of these are provided in Appendix F. Based on a number of studies, DEFRA make the general assumption that the capital costs for SUDS are on a par with traditional drainage systems (DEFRA, 2011; DEFRA, 2009), though this is considered conservative as case studies have also suggested that SUDS may be up to 30% cheaper to construct for sites that don't pose significant challenge (DEFRA, 2011).

8.3. Land take costs can be the most significant factor influencing capital costs for SUDS schemes (Woods Ballard, *et al.,* 2015). Whether or not the cost of land should be considered within a whole life assessment depends on if the land is used for SUDS alone, or has other uses such as car parking, recreational space or forms part of community open space requirements.

Maintenance costs

8.4. Maintenance costs for SUDS have also been assessed from a number of sources and a summary is provided in Annex F Table F4.

8.5. SUDS Schemes that rely on natural planting will need specialist horticultural care in the period after construction whilst they become established to ensure they provide the expected service. It is usually recommended that this is included in the construction contract and is the responsibility of the contractor (Woods Ballard, *et al.*, 2015). Extra costs may also arise during an inundation event.

8.6. The high level impact assessments for the UK Flood and Water Management Act 2010 (Defra, 2011) (Defra, 2009) determined that the cost of maintenance of a traditional pipe system was on average £40 per property. SUDS schemes were assessed to be £6/per property more expensive than a traditional system, although this is acknowledge to be conservative as there are many cases where SUDS can be cheaper (Royal Haskoning, 2012).

Whole life comparative costs

8.7. A simple, high level costing tool is available on the UKSUDS website: www.uksuds.com - SUDS construction and maintenance cost calculator. This provides indicative costs for different types of SUDS components, but can also be used with site-specific costs input by the user to calculate whole-life costs for a SUDS scheme. The tool can calculate capital and maintenance costs and in turn calculates the whole life cost of the scheme. Whole life carbon saving costs can also be accounted for. Tools such as SCOTSNET (SCOTSNET, 2010) can be used to calculate whole life costs and whole life carbon costs for road drainage.

8.8. SUDS can be a cost effective alternative to conventional drainage when included early in the planning process – it is the failure to consider SUDS at the very start of a developments design that can be significant barrier to cost effective delivery (CIWEM, 2019).

8.9. Costs avoided: The total cost of a SUDS scheme should not be compared with only the capital and operational costs of a below ground piped drainage system if the

SUDS provides much more – e.g. recreational space, car parking – these additional costs for a traditional piped system should also be added on as savings.

8.10. Delivering SUDS schemes through partnerships is becoming more common in the UK. Partnerships have advantages that there may be (a) more than one source of capital funding and (b) a shared responsibility for long-term costs. However potential partners will want to know how and why they should help with funding and what the benefits will be for them, e.g. local authorities, Manx utilities and DEFA.

Returns

8.11. The benefits of SUDS have already been outlined in Sections 3 and 5, attributing a financial figure to these benefits however can be difficult as many of the ecosystem services provided are not valued by conventional markets.

8.12. CIRIA has developed a free tool and guidance, B£ST (Benefits Estimation Tool – valuing the benefits of blue-green infrastructure). It is used to assess and monetise many of the financial, social and environmental benefits of blue-green infrastructure. The results enable users to understand and quantify the wider value of SUDS and natural flood management measures. This can support investment decisions and can help to identify stakeholders and find potential funding routes.

8.13. Susdrain (Susdrain, 2019) also presents a number of case studies outlining the returns of SUDS schemes. The Lamb Drove example in Cambridge suggest around a 10% saving on capital costs with the SUDS scheme. It’s been suggested that the savings could have been greater if the SUDS layout had been considered earlier in the development.

8.14. DEFRA, as part of the work on the Flood and Water Management Act, has also undertaken a number of comparative studies on the costs and benefits of traditional drainage and SUDS. The sites they looked at included:

8.15. Mixed housing development, Daniels Cross, Shropshire

8.16. Rail freight terminal, Telford, Shropshire

8.17. School, Redhill, Worcester

8.18. Housing, Islington, London

8.19. Mixed housing development, Hadley, Shropshire

8.20. All of the sites in these studies showed that the inclusion of SUDS was cheaper than a traditional drainage system.

8.21. Whichever mechanism or tool is used to assess the cost/benefit analysis of SUDS it should be robust, transparent and open to scrutiny.

8.22. When presenting the benefits of SUDS schemes it can be helpful for buy-in if the approximate timescales for benefits to accrue are shown; see Table 6 for example benefits and timescales.

Table 6: SUDS Benefit timescales

SUDS Benefit	**Benefit Timescale**
Flood risk reduction	immediate
Recreation	immediate
Ground water recharge	medium term
air quality improvements	medium term
climate resilience	long term
carbon sequestration	long term

9. CONCLUSIONS

9.1. Surface water flooding is a problem that is likely to increase due to factors such as urbanisation and climate change.

9.2. SUDS manage surface water runoff in a more holistic and sustainable way that considers water quantity, water quality, biodiversity and amenity outcomes, as well as offering additional benefits of climate change adaptation and mitigation.

9.3. There is an opportunity to increase the use of SUDS on the Island through the development of a SUDS policy. The policy should be based around a set of clear principals which support an holistic, equitable and beneficial approach to surface water management. Suggested policy principals and supporting details are provided in this report but will require further development by the relevant stakeholders.

9.4. To aid the deliverance of water quality improvements through SUDS, water quality standards should be developed for receiving water bodies. For example the Isle of Man should consider adopting the water quality standards set out in the Water Framework Directive and SUDS should be designed to meet these standards.

9.5. To aid the deliverance of biodiversity improvements SUDS should link with local biodiversity action plans where possible and access to any biodiversity funding should be made available to SUDS development where the biodiversity criteria can be shown to be met by the SUDS.

9.6. The contribution of SUDS to carbon sequestration targets are likely to be small for both "necessary" and "high ambition" pathways (estimated as 0.1% and 0.24% of the Isle of Man total emissions budget for 2017 respectively). The opportunities for SUDS to support carbon sequestration are likely to require further study.

9.7. The barriers to SUDS have been explored in this report as well as suggested approaches to overcome these. Most of the technical, practical and social barriers to SUDS are likely to be overcome in most situations, however key to this will be the establishment of an appropriately resourced adoption body (or bodies) with clear roles and responsibilities for developers, planners and those adopting and maintaining SUDS.

9.8. Consideration should be given to educating end users on the role of SUDS.

9.9. The adoption body should set approval criteria and establish a process by which SUDS are adopted.

9.10. In the UK (with the exception of Scotland) SUDS have not been widely implemented due to a weak statutory position. The Isle of Man should avoid this situation developing by a robust legislative and planning framework for SUDS.

9.11. The design and construction guides Manx Sewers for Adoption, and Manual for Manx Roads will need to be reviewed and updated to support SUDS policy and adoption.

9.12. The current planning and building control regulatory frameworks should be reviewed to ensure that all the proposals align and maximise the benefit of the high level SUDS requirements for effective catchment wide surface water management and develop new policy principles where needed or expand on those already in existence. A review of the Strategic Plan (2016) is proposed in 2020 as part of the Planning Action Plan which could include high level SUDS requirements.

9.13. The costs (and returns) of SUDS will vary from site to site, however studies have shown that capital costs are typically on a par with, or lower than, conventional pipe based solutions. Maintenance costs are however, on average, higher than traditional solutions.

9.14. The development of a Manx SUDS policy, supported by an appropriately resourced planning, advisory and adoption bodies, is likely to bring multiple benefits to Manx communities, including improved flood risk management, climate change resilience, more visible and connected habitats as well as ecosystem services including carbon sequestration.

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Annex A
Potential Carbon Savings from minimising surface water in the combined sewerage system

- Sewage base flows to Meary Veg are around 300L/S
- During heavy downpour events flows can increase to around 700-1000L/sec
- Not all of this additional load would be treated though as Meary Veg has a max treatment capacity of 400L/s, so anything over this spills to sea in a very diluted form.
- Power requirements to pump and treat sewage at Meary Veg from the Douglas catchment are approximately 0.7kW/m3
- The carbon intensity of electricity produced by Manx utilities is approximately 0.426kg/Kwh
- Potential carbon savings for every 1000L of surface water removed from are:
- 0.7 x 0.426 =0.2982kg CO_2/m3 ROUGHLY 300g CO_2 per 1000L of sewage treated, although this will be reduced under extreme storm events when overspills occur.

Annex B
Example SUDS design criteria and example indicators

SUDS design criterion	**Example indicator**
Use surface water runoff as a resource	A proportion of runoff from rainfall events is harvested for use or infiltrated to support river base flows and/or recharge groundwater.
Support the effective management of flood risk in the receiving catchment	Discharges to surface waters are prioritised over discharges to sewers. The rates and volumes of runoff for high return period events are controlled in accordance with the water quantity standards
Preserve and protect natural hydrological systems on the site	The natural hydrological drainage systems on the site are preserved or enhanced as part of the landscape and/or surface water management system.
Manage on-site Flood risk	Runoff from rainfall events that exceeds the SUDS capacity is managed in identified exceedance routes and storage areas.
Design in system flexibility/adaptability to cope with future change	The SUDS design includes climate change and urban creep allowances, or is designed with the flexibility (and funding) to be suitably adapted during its design life.
Protect water quality of receiving water bodies	Interception to help facilitate the retention of pollutants in surface vegetation, soils or pervious surfaces. Treatment processes to reduce contaminant levels where necessary. Risk based approach.
Maximise multi-functionality	The number, variety and quality of additional and multi-functional uses for SUDS such as recreational areas, car parking, traffic management, accessibility of grey water for community re-use eg in allotments.
Enhance visual character	The proportion of the drainage system that is designed to be visually attractive.
Facilitates community engagement	Extent to which the community can see and interact with elements of the SUDS – water play areas, hand pumps etc.
Safe	Consideration of public safety within SUDS designed for amenity use.
Support and protect natural local habitat and species	The extent, quality and significance of local habitats supported or enhanced by the SUDS design. Appropriateness of species/habitats supported in the given surroundings. Link with local biodiversity plans where possible.
Contribute to habitat connectivity (link to WP 7)	The extent to which the SUDS scheme is integrated with wider green infrastructure strategies, or is helping to support or connect habitats.

Annex C
Potential carbon sequestration from driveways converted to permeable paving.

	1971	Percent	2004	Percent	%Change
Paved garden area (Km2)	0.08		0.19		138
Average paved garden size (m2)	39		53		36
No of properties with paved front gardens	2,130	71	2,700	90	19

This previous study suggests only 10% of houses haven't paved their front gardens.

Applying this figure to the Isle of Man provides the following result:

Isle of Man Households	43,000	From 2016 census
Households with gardens	21,500	In absence of clear on proportion of households with gardens, assume 50%
Since 2004, remaining households with non-paved gardens	2,150	Assuming 10% have not paved gardens, as per the research above
Using 2004 paved garden size, available area for paved parking (m2)	114,810	Using UK paved garden size in 2004 from existing study
Percentage of houses assumed to covert to permeable paving driveways from henceforth	50%	This figure can be amended to input a different assumption
Area of driveways converted to permeable parking in this scenario (m2)	57,405	
Average Carbon Sequestration rate (kg C m-2 yr-1)	0.04	
Kg carbon sequestration per year	2,296	

Annex D
Potential carbon sequestration from adoption of green roofs in new developments

Type	2016 IoM housing stock - numbers of houses by property type from https://www.gov.im/media/1361664/2018-02-08-2017-housing-market-report.pdf	Current proportion of housing stock by property type (if you know the proportion of property types in future developments between 2020 and 2026 you can change these % to give you a different output of the total roof area which would be more accurate)	Number of new houses by property type (this is taking the expected housing requirements total and splitting up by proportion of existing housing stock)	Average area of house type (square feet) from https://www.dwh.co.uk/library/Average-UK-house-sizes/	Average area of house (square meter)	Average area of roof (square meter) from website	Total roof area available per property type (square meter) **	Total roof area available (hectares)
Detached	13964	39%	1,991	1582	147	195.4	389,108.42	38.91
Semi detached	7667	21%	1,093	1033	96	132.7	145,088.38	14.51
Terraced	7630	21%	1,088	887.5	82	115.2	125,346.80	12.53
Purpose built flat	4451	12%	635	656	61	88.64	56,263.09	5.63
Flat in converted house	1627	5%	232	656	61	88.64	20,566.18	2.06
Other	424	1%	60	962.9	89	123.9	7,491.58	0.75
Total	35763		5,100				Total roof area of all property types added together in order to meet expected housing requirements of 5100 *	74.39
Additional dwellings in meeting expected housing requirements - from workpackage report (you might want to change this figure to	5100						*roofs of greater than 9.5° pitch generally have specific design requirements for green roofs https://www.thegreenroofcentre.co.uk/green_roofs/faq.html	
							** Using roof pitch of 6/12 and eaves sticking out of 0.5m	
							from https://www.calculator.net/roofing-calculator.html?	

Annex E
SUDS Risk Assessment Matrix (from Woods Ballard, *et al.*, 2015)

		Consequence				
		Insignificant	**Minor**	**Moderate**	**Major**	**Extreme**
Likelihood		No injury or health effects	Minor injury or health effects	Injury but not life threatening Some ill health effects	Serious injury Dangerous near miss Serious ill health	Serious injury or death Serious life-threatening disease.
Almost certain (frequent)	Is expected to occur/ recur frequently or within a short period of time (most weeks or months)	M	M	H	E	E
Likely (probable)	Will probably occur/ recur in most circumstances (several times a year)	L	M	H	H	E
Possible (occasional)	Possibly will occur/ recur occasionally (once every few years)	L	M	M	H	H
Unlikely (uncommon)	Uncommon might occur/ recur at some time in the future	L	L	M	M	H
Rare (remote)	Unlikely to occur/ recur May only happen in exceptional circumstances	L	L	L	L	M

Annex F
SUDS costs

Table F1: Capital costs of SUDS components (HR Wallingford, 2004)

SUDS Measure	Capital Expenditure (2002)	
	Cost £	**Unit**
Filter drain	100 - 140	/m^3 stored volume
Infiltration trench	55 - 65	/m^3 stored volume
Soakaway	> 100	/m^3 stored volume
Permeable pavement	200 - 250	/m^3 stored volume (assuming depth 0.3m, void ratio: 0.3)
Infiltration basin	10 - 15	/m^3 detention volume
Detention basin	15 - 20	/m^3 detention volume
Wetland	25 -30	/m^3 treatment volume
Retention pond	15 - 25	/m^3 treatment volume
Swale	10 - 15	/m^2 swale area
Filter strip	2 - 4	/m^2 filter strip area

Table F2: Capital costs of green roofs (The Solution Organisation, 2005)

SUDS Measure	Capital Expenditure (2005)	
	Cost £	**Unit**
Exposed roof	47	/m^2
Covered roof with sedum mat	93	/m^2
Biodiverse covered roof	97	/m^2

Table F3: Capital costs of retrofit SUDS (Stovin & Swan, 2007)

SUDS Measure	Capital Expenditure (2002)		
(retrofit)	**Upper Cost**	**Lower cost**	**Unit**
Water butt (0.3m^3)	243	100	/property
Infiltration trench	99	74	/m
Swale	20	18	/m

Soakaway	552	454	/soakaway
Porous car park (grasscrete	63	63	/m^2
Pond/basin	55	35	/m^3
Storage tank (concrete)	518	449	/m^3

Table F4: Annual maintenance costs for SUDS

SUDS Feature	**Unit costs £** (updated to 2011 prices using consumer price index)			**Unit**	**Data Source**
	Low	**Med**	**High**		
Filter drain	0.3	0.8	1.3	/m^3 stored volume	HR Wallingford (2004)
Infiltration trench	0.3	0.8	1.3	/m^3 stored volume	HR Wallingford (2004)
Soakaway	0.1	0.1	0.1	/m^2 treated area	HR Wallingford (2004)
Permeable pavement	0.6	1.0	1.3	/m^3 stored volume	HR Wallingford (2004)
Infiltration basin	0.1	0.3	0.4	/m^2 infiltration basin area	HR Wallingford (2004)
Detention basin	0.1	0.3	0.4	/m^2 detention basin area	HR Wallingford (2004)
Wetland	0.1	0.1	0.1	/m^2 wetland surface area	HR Wallingford (2004)
Retention pond	0.6	1.3	1.9	/m^2 pond surface area	HR Wallingford (2004)
Swale	0.1	0.1	0.1	/m^2 swale area	Average of CIRIA (2007), Environment Agency (2007)and Stovin and Swan (2007)

Filter strip	0.1	0.1	0.1	/m^2 filter strip area	HR Wallingford (2004)
Exposed green roof	0.2	0.2	0.2	/m^2 surface area	Solution Organisation (2005)
Green roof covered with sedum mat	0.7	0.7	0.7	/m^2 surface area	Solution Organisation (2005)
Biodiverse green roof	0.2	0.2	0.2	/m^2 surface area	Solution Organisation (2005)
Water butt	N/A	N/A	N/A	N/A	N/A
Rainwater harvesting	120	120	120	/property	Roebuck (2008)
Storage tanks	Unknown	Unknown	Unknown	Unknown	Unknown

Annex G
Stakeholder/consultee comments

- SUDS can be included in basically any site regardless of the size of the site. Developers will obviously argue that they can't due to land use or constraints but with proper early planning this can be overcome.
- A concern has been raised regarding the suggestion for developers to provide operation and maintenance manuals to adoption bodies as part of CDM Health and Safety documentation. The view is expressed that this level of detail should not be required at the planning stage due to the sunk costs incurred by the developers should an application be refused.
- A concern has been raised that developers should not be required to provide full construction details at the planning stage, again due to the sunk costs incurred by the developers should an application be refused. Only once approval is granted developers will undertake ground investigations etc. and provide full engineering details.
- If designed correctly and to UK guidance all H&S issues should be addressed.
- When the Governors Hill Ponds when built in the 1990's, The Royal Society Prevention Accidents (RoSPA) were asked to do an assessment by the developer in order that the H&S issue were all addressed.
- All new developments since 2001 require surface water attenuation if they discharge into surface water sewers or watercourses. As Manx Utilities have a long standing stance of not adopting any above ground attenuation, all such structures are constructed below ground and are specifically designed for the development and are not retrofitted.
- Manx Utilities publishes "Manx Sewers for Adoption: A design and construction guide for developers working in the Isle of Man" which specifies criteria for adopting sewers. This could be updated to include SUDS and could be a mechanism for driving forward SUDS.
- It is sometimes permitted for surface water flows to be discharged un-attenuated directly to an adjacent watercourse depending on its proximity to the sea. In these cases the receiving watercourse will be assessed to determine whether the peak flows arriving from the upstream catchment will impact on any restricted SW discharge from the development.
- Design standards should be set bearing in mind that (climate) records are falling every year.
- Is the DEFA Planning Department the correct Government body to set catchment wide surface water management objectives?

- Poor knowledge of the implementation and construction of SUDS should be explored further as a potential barrier to SUDS.

- Policy still reactive, e.g. tied to Planning applications. To be effective as an adaptation mechanism, what is required is a combined, strategic catchment runoff attenuation, planting and biodiversity programme, actively planning and implementing sustainable development of Island catchments.

- Experience shows that developers will always choose the drainage option that is most financially beneficial to the developer. Where a SUDS solution is cheaper than a traditional drainage solution SUDS will be promoted, but it is usually the case that a traditional scheme is implemented. If the cost of implementing sustainable solutions were on-a-par with, or cheaper than traditional methods, as the report hints at by providing a few examples, developers would already be implementing them.

- The Department of Infrastructure issues "Manual for Manx Roads - A Design and Construction Guide" in which it states the following:

- There is no requirement in Manx legislation to provide sustainable drainage systems (SUDS), as there is in UK law. Some SUDS may be considered for adoption, but due to their potentially high maintenance costs there may also be a requirement for commuted sums to be provided by the developer. Discussions should be held at a very early stage with the Department (of Infrastructure) if there are proposals to use SUDS in the highway drainage systems.

- The Department (of Infrastructure) will not normally adopt soakaways as part of highway drainage. This is due to the anticipated higher maintenance costs, and potential capacity issues with unpredictable weather patterns in the future.

- Clearly, the Manual for Manx Roads would need to be amended depending on the new policy, but SUDS have been resisted for adoption in the past mainly due to uncertainty about future maintenance and replacement costs.

- Identifying the body with future responsibility for SUDS is a stumbling block at present; no-one wants to take on the maintenance liability of an attenuation pond. We again know from experience that if the responsibility for future maintenance rests with the developer (or their management company), it can be problematic when the developer eventually ceases to exist. This all needs clarification in the policy.

- From a highway perspective, the highway authority has a duty to maintain highways maintainable at public expense, which requires the DOI to provide an adequate drainage system and keep the highways free from flooding. Any SUDS policy would need not to conflict with the DOI's statutory duties.

- It is generally beneficial to the highway construction to prevent the fabric of the highway from becoming saturated by ensuring there is adequate surface and subsurface drainage provision. Any policy proposals for increased infiltration (e.g. via pervious or permeable surfaces) should be checked to ensure they don’t negatively impact on the highway foundations.

- There is an opportunity to highlight the potential carbon savings from reduced use of cement if replaced by natural environments.