Nr. 18 - 2019

REPORT

DOCUMENTATION TOOL OF NATURE-BASED SOLUTIONS

– a guideline

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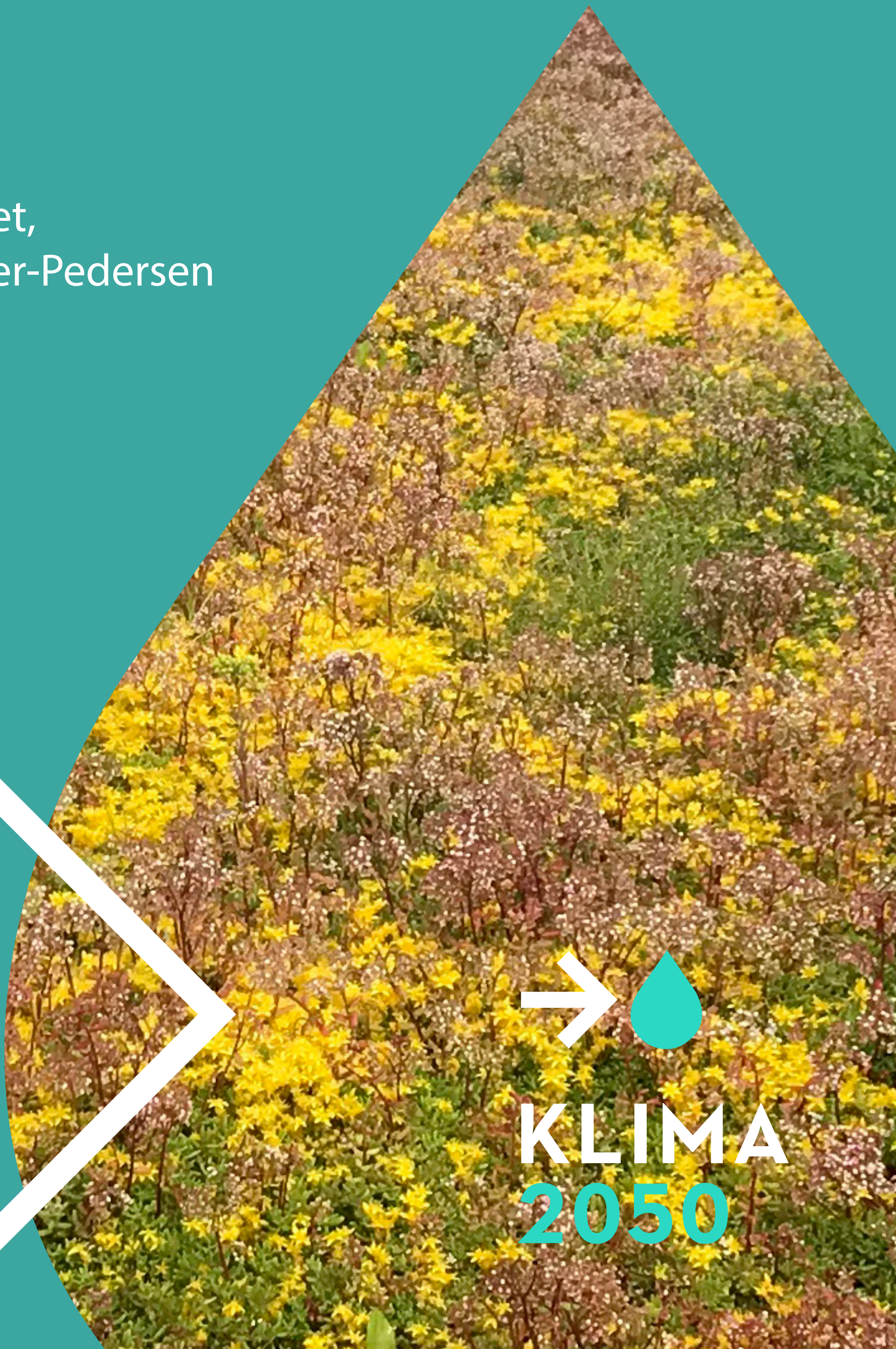

KLIMA 2050

Klima 2050 Report No 18
Documentation tool of nature-based solutions – a guideline
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Keywords: nature-based solutions, documentation, data structure, operation and maintenance, sensors
ISBN: 978-82-536-1642-1
Publisher: SINTEF Community, Høgskoleringen 7 b, PO Box 4760 Sluppen, N-7465 Trondheim
www.klima2050.no
Illustration front cover and page 3: Klima 2050

Preface

This report deals with the need for a general NBS (nature-based solution) documentation tool consisting of 'data structure' that allows asset managers to register useful and necessary information of NBS. The data structure presented in this guideline should be adaptable to different NBS types and allow multiple benefits to different actors/stakeholders depending on their specific interests on the subject. This guideline also provides a few examples of sensors applications and application of data structure for two Klima 2050 pilots and a commercial, prefabricated NBS product.

Klima 2050 - Risk reduction through climate adaptation of buildings and infrastructure is a Centre for Research-based Innovation (SFI) financed by the Research Council of Norway and the consortium partners. The SFI status enables long-term research in close collaboration with private and public sector, as well as other research partners aiming to strengthen Norway's innovation ability and competitiveness within climate adaptation. The composition of the consortium is vital in order to being able to reduce the societal risks associated with climate change.

The Centre will strengthen companies' innovation capacity through a focus on long-term research. It is also a clear objective to facilitate close cooperation between R&D-performing companies and prominent research groups. Emphasis will be placed on development of moisture-resilient buildings, stormwater management, blue-green solutions, measures for prevention of water-triggered landslides, socio-economic incentives and decision-making processes. Both extreme weather and gradual changes in the climate will be addressed.

The host institution for SFI Klima 2050 is SINTEF, and the Centre is directed in cooperation with NTNU. The other research partners are BI Norwegian Business School, Norwegian Geotechnical Institute (NGI), and Norwegian Meteorological Institute (MET Norway).

The business partners represent important parts of Norwegian building industry; consultants, entrepreneurs and producers of construction materials and technology: Skanska Norway, Multiconsult AS, Mestergruppen Arkitekter AS, Norgeshus AS, Leca AS, Skjæveland Gruppen, Isola AS and Powel AS. The Centre also includes important public builders and property developers: Statsbygg, Statens vegvesen, Jernbanedirektoratet and Avinor AS. Key actors are also Trondheim kommune, The Norwegian Water Resources and Energy Directorate (NVE) and Finance Norway.

Trondheim, 5th of November 2019

Berit Time
Centre Director
SINTEF Community

Summary

Nature-based solutions (NBS) can be found in many forms and variations that make information of specific aspects connected to them are difficult to populate. As an asset, NBS should be managed properly right from the beginning of planning, design, and construction process, up to the operation and maintenance phase. On the other hand, decision-making in asset management of water-related infrastructures depends strongly on the available data on the assets' characteristics and operation and maintenance (O&M) activities. Thus, the need for a general NBS documentation tool consisting of 'data structure' that allows asset managers to register useful and necessary information of NBS, is of paramount importance.

The data structure presented in this guideline should be adaptable to different NBS types and allow multiple benefits to different actors/stakeholders depending on their specific interests on the subject. The data structure should also be flexible to account for a 'system solution' i.e. to assess the combined effects of two or more NBS in parallel or serial arrangement.

Installation of sensors can improve monitoring of NBS performance and status in a more quantitative way. This would also contribute to asses necessary maintenance action and/or rehabilitation of NBS during its operation period. However, NBS promises low cost of construction, operation and maintenance and sensor installation may contribute a significant amount of expenses/investment and possible operational costs. Hence, a careful consideration of sensor type(s) and monitored parameter(s) must be taken if NBS type of installation is to be equipped with sensors and to what extend these sensors are beneficial in supporting the operation of NBS. This guideline provides a few examples of sensors applications and application of data structure for two KLIMA2050 pilots and a commercial, prefabricated NBS product.

Content

1 Introduction

1.1 The need for documentation of nature-based solutions

Nature-based solutions (NBS) use the features and processes of a natural complex system such as their ability to store carbon and regulate water flow to achieve desired outcomes e.g. reduced disaster risk, improved human well-being and socially inclusive green growth. NBS are ideally energy-efficient, resource-efficient and resilient to change, but to be successfully implemented they must be adapted to local conditions and must undergo proper planning, design, operation, and regular maintenance activities.

NBS can be found in many forms and variations that make information of specific aspects connected to them are difficult to populate. As an asset, NBS should be managed properly right from the beginning of planning, design, and construction process, up to the operation and maintenance phase. On the other hand, decision-making in asset management of water-related infrastructures depends strongly on the available data on the assets' characteristics and operation and maintenance (O&M) activities. Thus, the need for a general NBS documentation tool consisting of 'data structure' that allows asset managers to register useful and necessary information of NBS, is of paramount importance. This data structure should be adaptable to different NBS types and allow multiple benefits to different actors/stakeholders depending on their specific interests on the subject. The data structure should also be flexible to account for a 'system solution' i.e. to assess the combined effects of two or more NBS in parallel or serial arrangement.

1.2 Purpose of the guideline

This guideline presents a standard NBS data structure in a form of a documentation tool that allows a step-by-step way to present specific information about an NBS installation with some examples of its implementation as a stand-alone unit or in combination with more NBS.

1.3 Who should use this guideline?

The NBS documentation tool is applicable for a broad spectrum of users. The following benefits for different actors, but not limited to, can be foreseen:

- **For owners**: The data structure should allow direct comparison of NBS alternatives one wishes to implement. In addition, the data structure can be used as a check list to know details required in each phase of NBS implementation, from planning to operation and maintenance phase.

- **For planners and constructors:** Even if NBS is designed as a simple construction, it still requires careful planning and construction to meet its design requirements. The data structure would provide planners and constructors with a list of considerations, not only to controlling water quality, improving water quality, but also providing opportunities for realizing co-benefits, amenity and improving biodiversity.

- **For technology suppliers**: The data structure provides a clear guideline for type of information necessary to present for their potential customers and for certification purposes. The data structure can be also viewed as a growing working document for their products as more information may be added as experience from previous implementation is recorded. The benefit should extend beyond producers of NBS, but also other business niches that have interests in NBS implementation. For example, IT companies that provide development of databases. The data structure should give a standardized format of information to show in their databases.

- **For authorities**: The data structure should allow an easy way to assess the expected performance of NBS, for example to achieve a certain discharge volume or to assess implementation of NBS required to mitigate the impact of climate change/ extreme weather events.

- **For certifying bodies**: The data structure should allow a structured assessment of an NBS product and standardization of necessary features of NBS.

2 NBS documentation tool

2.1 Main features of the data structure

Table 1 show the main features of the data structure in the NBS documentation tool. In total, there are eight types of information required in the data structure and each has its own specific elements to be provided by the actors as will be specified in the following sections. The main features are categorized into 8 main items and further divided into different types of information. The specific elements of information listed in 'Documentation required' column for each type of information are divided into two type of elements: standard elements and solution specific information. Standard elements are considered those that are common for all types of NBS, while solution specific information depends on the type of NBS in question. Detail description of each element is given in the following sub-chapters.

It should be noted that even though the data structure was developed in close collaboration with KLIMA 2050 industrial partners, it is still a subject for future modifications.

Table 1.Main features of the data structure

ID	Information required	Type of information	Documentation required	Description/input data
1	Name	Product/solution name		
2	Type of NBS	Refer to https://ovase.no/wiki		
3	System Description	Description of the product/solution		
4	Planning	General considerations		
		Selection of siting		
5	Design	Water quantity		
		Water quality		
		Amenity (co-benefits)		
		Cost element		
		Data management		
		Sensor		
6	Operation	Regular inspections		
7	Maintenance	Regular maintenance		
		Remedial actions		
8	Additional reference	Refer to publications, brochures, etc.		

2.2 Name and type of NBS

NBS's name and type are parts of the general information that are firstly inquired in the data structure (Table 2). The name can refer to a specific product of the NBS in cases where the NBS solution is a prefabricated/purchased commercial solution but can also be a generic name preferred by the stakeholder filling in data in the NBS documentation tool. There is, however, a need to standardize the types of NBS for a better classification, since one solution may be referred to as several names depending on the reference used for classification. The list of NBS types available in OVASE (www.ovase.no) is used as reference in the documentation tool to ensure coherency with the other tasks in KLIMA2050.

Table 2 General information of the NBS solution/product.

ID	Information required	Type of information	Documentation required	Description/input data
1	Name	Product/solution name		
2	Type of NBS	Refer to https://ovase.no/wiki		

2.3 System description

NBS is mainly designed to manage water quantity. Detailed descriptions of the solution related to achieving the main goal of NBS shall be provided in the data structure. There are a number of specific information required that include the dimension of the NBS solution, and the main features of the NBS i.e. volume, peak flow, and flow exceedance control of the NBS. These four elements are thought essential since the main goal of NBS is in general stormwater runoff volume reduction.

Information on NBS dimension shall be given in highest possible details. This includes any NBS specific parameters such as peripheral systems (i.e. sublayers, underdrain, etc.). Inlet and outlet are essentials for NBS to control the volume retention and rate of discharge flowing in and out of the NBS. Thus, detail information about the levels and correct installation is particularly important to fulfill the design requirements.

Since the runoff volume from NBS can be as damaging to downstream flood risk as peak flow rates, it is necessary to ensure the runoff volume discharged during extreme events are also controlled. This dictates that the runoff volume from a site with NBS should not exceed that of without NBS. The control system shall be explained adequately in the data structure.

Peak runoff rates from the site during rainfall events is likely to be significant for the capacity of receiving sewer/water bodies. This as well shall be constrained to the runoff from that of an undeveloped site and shall be recorded in the data structure.

NBS should be fully protected against flooding from the drainage system. Thus, higher return periods should be specified for the exceedance flow. Information on exceedance flow control (return period used in the calculation of drainage, drainage system, etc.) shall also be given in good details.

Table 3 Specific description of the system.

ID	Information required	Type of information	Documentation required	Description/input data
3	System Description	Description of the product/solution	Dimension	
			Volume control	
			Peak flow control	
			Exceedance flow control	
			Solution specific parameters	

2.4 Planning phase

The inclusion of planning phase in the documentation tool is meant to record information about the site, its design and physical constraints that can help avoid NBS operation challenges. General NBS site information such as accessibility, drainage management, equipment and skill required for maintenance shall be explained adequately. Information about project phasing can be of benefit especially if the NBS is built in the same period as other construction works at the same site.

Selection of site for NBS is of paramount importance. Since NBS focuses mainly on managing the water quantity, information about existing water systems/courses/drainage is needed. In extreme events water can flow directly onto the NBS site and, hence, prevention measures shall be in place and explained adequately.

Specific issues related to the type of NBS built shall also be mentioned and identified in the data structure. For example, getting the right materials for the NBS and possible substitution if applicable, infiltration potential of the site and risk of increase groundwater table owing to infiltration from the NBS, existing water system/courses around the NBS site, are some of the planning aspects that may impact the performance of the NBS.

Table 4 Documentation required in planning phase.

ID	Information required	Type of information	Documentation required	Description/input data
4	Planning	General considerations	Accessibility requirements	
			Management of drainage	
			Maintenance skills,equipment and time input required	
			Project phasing	
			Expected performance	
			Solution specific issues	
		Selection of siting	Exisiting water systems/ courses	
			Potential overland flow/ infiltration issues	
			Solution specific issues	

2.5 Design phase

The type of information in the design phase (Table 5) required in the data structure is related to the general functionality of the NBS. There are three aspects of NBS functionality that are covered in the data structure, i.e. aspects related to water quantity and quality management, and expected co-benefits gained from applying the NBS.

The hydraulic design of NBS including the control systems for peak flow, volume, and exceedance flow shall be registered and explained. Water quality coming out of NBS should not deteriorate and, moreover, NBS is reckoned to exert a certain degree of capability to improve the water quality. This is particularly relevant for NBS that handle surface runoff from urban areas (e.g. streets, highways, roofs, etc.). Any expected impacts on water quality shall be mentioned in the data structure.

Co-benefits are an additional aspect offered by NBS over the other stormwater solutions in urban areas. The data structure lists a number of known co-benefits of applying NBS such as multi-function use of space, reduction of heat-island effect. Other co-benefits that may be solution dependent may also be registered.

NBS promises a robust yet economical solution for stormwater management. Therefore, cost element of NBS construction should be indicated. Additional costs related to operation and maintenance of NBS shall be assessed from the design stage and be part of consideration of choosing any particular NBS.

The NBS is expected to fulfill its functionality in a certain lifetime. Maintenance program is meant for ensuring that the NBS can comply with the design goal or expected performance. Installation of sensors and data management are two aspects that can improve operation and maintenance of an NBS. With recent development, these two aspects are included in the data structure and should be part of consideration in the design stage of NBS. On one hand, choice of sensors depends on the goal of their application and maybe solution specific. On the other hand, sensors and data management can add up to the cost element of NBS. Thus, installation of the right sensor(s) to monitor the right parameter(s) is utmost beneficial. The discussion on sensors and parameters to monitor is presented in Chapter 3 of this guideline.

Table 5 Documentation required in the design phase.

ID	Information required	Type of information	Documentation required	Description/input data
5	Design	Water quantity	Hydraulic design	
			Peak flow control	
			Volume control	
			Exceedance flow	
			Solution dependent	
		Water quality	Impact on water quality	
			Discharge quality	
			Solution dependent	
		Amenity (co-benefits)	Multi-functional use of space	
			Reduction of heat-island effect	
			Adaptability	
			Recreational	
			Environmental foot-print	
			Bio-diversity	
			Solution dependent	
		Cost element	Unit price	
			Other cost consideration	
			Solution dependent	
		Data mangement	Monitoringof performance (Water quantity/quality/ amenity, etc)	
			Solution dependent	
		Sensor	Application of sensor(s) Goal, type, location	
			Monitoring of specific parameter(s)	
			Solution dependent	

2.6 Operation phase

Table 6 presents the elements of data structure for operation phase. Information on regular inspection regime shall be provided. This includes different type of actions necessary to keep the operation of NBS at expected level. Frequency of these actions, procedure that must be followed, and contact/responsible person shall be stated clearly. Regular inspections, however, should include simple and uncomplicated actions, and the list of actions should not be too extensive and aimed at preventive measures to keep the NBS performance at expected level.

Table 6 Documentation required in the operation phase.

ID	Information required	Type of information	Documentation required	Description/input data
6	Operation	Regular inspections	Type of action(s)	
			Frequency	
			Procedure	
			Responsibility	
			Data collection (type of data)	
			Diary function	
			Data assessments (O&M)	
			Solution specific issues	

Data collection from the operational phase of NBS is beneficial to assess the status and how well the installation is performing. The data can be used to better decide timely maintenance actions, whether it is regular or remedial maintenance that will be discussed in the preceding section. Diary function is something that can be of great benefit. The diary function should record/register any anomalies, changes, modifications, and/or actions done on NBS as such a complete history/record of actions is available should there be any problem occur in the future requiring information recorded.

2.7 Maintenance phase

In this guideline, the maintenance phase is characterized by two different types of actions (Table 7): regular maintenance and remedial actions. Regular maintenance requires more specific actions after a certain period of operation. Such actions are more elaborate compared to those of regular inspections, but also aimed at preventive measures to keep the level of NBS performance at expected level. On the other hand, remedial action deals with major actions aimed at correcting any faults and restoring the NBS performance closest to its design value. This also includes replacement/installation of NBS 'spare parts' if necessary. Consequently, remedial actions shall be executed by specialized/trained personnel in opposed to actions in regular inspection or maintenance that do not necessarily impose the same requirement.

For prefabricated NBS, user's manual from the technology provider can be a good reference for the type of maintenance actions needed. The SuDS Manual from CIRIA (https://www.susdrain.org/resources/SuDS_Manual.html) provides an extensive collection of various types on NBS that are not necessarily prefabricated and, thus, can also be used as an excellent reference for the non-prefabricated ones.

Table 7 Documentation required in the maintenance phase.

ID	Information required	Type of information	Documentation required	Description/input data
7	Maintenance	Regular maintenance	Type of action(s)	
			Frequency	
			Procedure	
			Responsibility	
			Solution specific issues	
		Regular maintenance	Type of action(s)	
			Procedure	
			Responsibility	
			Solution specific issues	
8	Additionalreferences	Refer to publication, brochures, etc.		

2.8 Additional reference

The last section in Table 7 refers to additional sources of documentation, for example scientific publications, brochures, standards, certification documentations, or any other types of document that may contain supporting information about the NBS.

2.9 Combined solutions

There are cases in which multiple NBS are installed/built in an area, whether in serial or parallel arrangement. In such cases, not only the overall performance out of this combination be an issue, but also the operation and maintenance of these NBS. The data structure shall include the overall impact of such a combination. Table 8 depicts the suggested appearance of the data structure with two combined NBS. The additional column should assess the expected combined effect that takes into account the type of arrangement these NBS have (parallel or serial).

The assessment of overall impact from NBS in series/parallel arrangement may initially be qualitative. As experience grow, such an assessment can be more quantitative. Involvement of modeling software that enables calculation of the overall impact is of highly relevant for this context.

Table 8 Documentation required for the combined system.

ID	Information required	Main categories	Documentation required	Description solution 1	Description solution 2	Comined System
1	Name	Product/solution name				
2	Type of NBS	Refer to https://ovase.no/wiki				
3	System Description	Description of the product/solution				
4	Planning	General considerations				
		Selection of siting				
5	Design	Water quantity				
		Water quality				
		Amenity (co-benefits)				
		Cost element				
		Data management				
		Sensor				
6	Operation	Regular inspections				
7	Maintenance	Regular maintenance				
		Remedial actions				
8	Additional reference	Refer to publications, brochures, etc.				

3 Some considerations about use of sensors

Application of sensors in NBS has been a focal point of discussion in recent years and is related to hot topics or buzzwords such as digitalization, internet-of-things, smart cities, integrated water management, etc. Information and communication technologies (ICT) can have a strong supporting role on development of NBS, for example inclusion of geographic information system, environmental data analysis, mobile phone apps for monitoring, planning and better management of NBS. Sensors, as an integral part of ICT, can also help measure the environmental impact of NBS compared to the more traditional solutions through a right data analysis. Sensors can also generate social benefits by raising/advocating general public awareness of NBS in solving urban problems through citizen projects and/or community-led urban development.

As discussed in Section 2.5, installation of sensors can improve monitoring of NBS performance and status in a more quantitative way. This would also contribute to asses necessary maintenance action and/or rehabilitation of NBS during its operation period. However, NBS promises low cost of construction, operation and maintenance and sensor installation may contribute a significant amount of expenses/investment and possible operational costs. Hence, a careful consideration of sensor type(s) and monitored parameter(s) must be taken if NBS type of installation is to be equipped with sensors and to what extend these sensors are beneficial in supporting the operation of NBS.

There are examples of various sensor applications for NBS in the literature as summarized in Table 9. The current list is far from extensive, but written materials (reports, publications, guidelines) are also abundantly available for the other NBS types. It is most important to understand that these applications are very much dependent on the aspects/parameters of NBS to monitor and are solution specific (depending on the type of NBS). The links provided for each example provide good details of the sensor types and installation which allow users of this guideline to evaluate the sensor(s) needed.

Table 9.Examples of sensor applications for NBS

ID	Type of NBS	Sensor/IoT			Reference
		Implementation/objective	Sensor type	Sensor location	
1	Green/grey roof	Monitoring of planth growth and greenroof performance	Moisture content, run-off composition, fire detection temperature and light levels	Green roof surface (moisture content, temperature, wind speed and direction, and other microclimatic sensors) Collection channel, gutter (flow meter, water level sensor)	https://www.forbes.com/sites/heatherclancy/2013/11/26/could-sensors-help-green-roofs-grow/#5055832d76bc
		Greenroof monitoring performance	Wind speed and direction, liquid precipitation, air temperature, relative humidity, and barometric pressure, water level sensor, moisture sensor, salinity and temperature		http://www.nexsens.com/case_studies/green_roof_monitoring.htm
		Energy and water balance study	Albedo, microclimate sensors	Green roof surface (moisture content, temperature, albedo, wind speed and direction, and other microclimatic sensors) Collection channel, gutter (flow meter, water level sensor)	https://www.mdpi.com/1424-8220/9/4/2647.htm
2	Infiltration systems	Performance monitoring	Flow Temperature	Collection channels Surrounding area	https://www.chijournal.org/Journals/PDF/C371
		Performance monitoring	Precipitation, temperature, relative humidity, wind speed and direction. Evapotranspiration, pollutant loading/waterquality Volume reduction, peakflow and storage, soil moisture and infiltration rate, water balance, storage and bypass	Collection channels Surrounding area	https://www.mdpi.com/2076-3298/4/1/2
		Infiltration capacity study	Electric resistivity, seismic refraction tomography	Soul subsurface	https://www.sciencedirect.com/science/article/pii/S1878029613003757
3	Swales	Vegetation establishment and growth	Inundation sensor, flow/flow resistance	Swale channel/surface	http://s46986.gridserver.com/resources/2001mazeretal.pdf
		Swale performance monitoring	Time-domain reflectometry, rain gauge (pluviometer) thermometer, relative humidity sensor, water table depth sensor Soil moisture, water level/pressure sensor	Swale channel/surface	https://lib.ugent.be/fulltxt/RUG01/002/377/152/RUGO1-002377152_2017_0001_AC.pdf
		Water quality and performance monitoring	Temperature, soil moisture, pH, turbidity, conductivity, ORP	Swale channel/surface	https://www.mdpi.com/1660-4601/15/3/537

Table 9.Examples of sensor applications for NBS (continued)

ID	Type of NBS	Sensor/IoT			Reference
		Implementation/objective	Sensor type	Sensor location	
4	Bioretention systems	Bioretention performance	Time-domain reflectometers: Soil moisture, temperature and conductivity Piezometers (Water depth) Pressure transducer and lysimeter Rain Gauge	Surface/sub-surface sensors Collection channels	https://www3.epa.gov/region1/npdes/stormwaer/research/epa-ord-final-report-sw-runoff-eval-report.pdf
		Comparative field-lab scale performance analysis	Flow meters, moisture sensor, WQ analyses	Surface/sub-surface sensors Collection channels	http://www.scielo.br/pdf/rbrh/v23/2318-0331-rbhr-23-e3.pdf
		Water quality		Surface/sub-surface sensors Collection channels	https://www.mdpi.com/2073-4441/6/4/1069
5	Pervious pavements	Performance of pervious pacements	Water level sensor, flow meter	Collection channel	https://brage.bibsys.no/xmlui/bitstream/handle/11250/2395326/14896_FULLTEXT.pdf?sequence=1
		Performance of pervious pacements	Water volume, flow, rain gauge, temperature	Collection channel Pavement surface	https://www.tandfonline.com/doi/abs/10.1080/17538947.2014.965880?src=recsys&journalCode=tjde20
		Clogging study	Infiltrometer	Pavement surface	http://crwp.org/files/OH_StormwaterControls_MonitoringReport2015.pdf
6	Ponds and wetlands	Long-term monitoring of wetland	Remote sensing, aerial photographs	Satellite images/drones	https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5422050/
		Performance monitoring	pH, salinity, temperature	Surface/sub-surface sensors	https://core.ac.uk/download/pdf/81105585.pdf
		Wetland hydrology monitoring	Piezometer, water level, pressure tranducers, tensiometers	Surface/sub-surface sensors	https://static1.squarespace.com/static/55c211c8e4b06ea5799e6c03/t/5609969ee4b012afaf1d1e5b/1443468958231/TroyerVaTechMS_WaterLevelsInClay2013.pdf

4 Solution specific data

Each category in the data structure indicates 'solution specific issues' or 'solution dependent' type of information. Indeed, there are certain aspects of planning, design, operation and maintenance that require specific attention depending on the type of NBS applied. This guideline uses the SuDS Manual from CIRIA (https://www.susdrain.org/resources/SuDS_Manual.html) [Woods et al. 2015] as a starting point of reference for such documentation owing to the excellent level of details given and the extensive list of NBS covered by the Manual. For prefabricated NBS products, the list of solution specific/dependent issues may be available in a much greater detail.

Table 10 lists some solution specific issues from planning to operation and maintenance phase of six NBS types extracted from CIRIA SuDS Manual. A specific column is also dedicated to 'important/critical parameters' that are relevant for design and/or operation and maintenance of NBS. Specific values that are recommended for each parameter are available in the Manual, but inclusion of such values is beyond the scope of this guideline.

Table 10.Solution specific issues for six NBS types extracted from CIRIA SuDS Manual

ID	Type of NBS	Planning	Design	Operation	Maintenance	Required documentation	Important/critical parameters
1	Green/gray roof	**General considerations:** • Accessibility requirements • Biodiversity objectives • Amenity/aesthetic objectives • Saturated weight of the system and loadbearing capacity of the roof • Additional loads: Imposed loads, including maintenance loadings and snow cover • Root penetration resistance of the water proof membrane • Resistance to wind shear and uplift • Growing medium • Suitability of the plants • Maintenance skills, equipment and time input required	**Selection of siting:** • Height of the roof • Exposure to wind • Exposure to sunlight • Bioregion/suitability of planting • Local biodiversity strategies	**Regular inspections (After severe storm/annually):** • Inspection of all components: Substrate, vegetation, drains, irrigateion, membrane, roof structure • Inspection of erosion and/or sedimentation • Inspection of drainage • Inspection of leakage/seepage underneath the green roof	**Regular maintenance (Six monthly or as required):** • Removal of debris and litter • Removal of dead plants • Removal of nuisance/invasive vegetation • Mowing of grasses, shrubs/bushes	• Dimension • Substrate information (type, depth) • Roof gradient • Type of plant • Type of grey roof material • Volume control • Peak flow control • Exceedance flow control	• Rain intensity • Flow • Soil moisture • Temperature • Wind • Light level • Salinity
			Hydraulic design: • See BS EN 12056-3:2000, Gravity drainage systems inside buildings - Part 3: Roof drainage, layout and calculatior • See BS 6229:2003, Flat roofs with continuously supported coverings. • Code of practice • Peak flow control • Volume control • Exceedance flow			**Remedial actions (As required):** • Reestablishment of soil substrate • Repair of erosion damage • Repair of physical damage	
			Physical construction requirements: • Fire resistance • Insulation • Roof pitch • Roof support • Water storage and irrigation • Access and safe working • Pretreatment and inlets • Outlets				

Table 10.Solution specific issues for six NBS types extracted from CIRIA SuDS Manual (continued)

ID	Type of NBS	Planning	Design	Operation	Maintenance	Required documentation	Important/critical parameters
2	Infiltration systems	**General considerations:** • Ground stability • Slope stability • Groundwater pollution • Grounwater flooding • Groundwater seepage	**Selection of siting:** • Infiltration capacity • Land use	**Regular inspections:** • Inspection of poor operation • Inspection of filter media and establishement of appropriate replacement frequency • Inspection of sedimentation/ accumulation and removal frequency • Inspection of inlet, outlets and overflows • Inspection of structure, pipe-lines, pretreatment systems	**Regular maintenance:** • Removal of debris and litter • Removal of sediment/oil/ grease/floatable • Change of filter media	• Dimension • Volume control • Peak flow control • Exceedance flow control • Plant height	• Rain intensity • Flow • Soil moisture • Temperature • Water level • Water quality
		Water quantity considerations: • Infiltration capacity • Depth of groundwater table	**Hydraulic design:** • See Chapter 25 CIRIA • Peak flow control • Volume control • Exceedance flow		**Remedial actions:** • Replacement of parts of infiltration structure		
		Water quality considerations: • Pretreatment • Potential pollution of ground-water	**Physical construction requirements:** • Pretreatment and inlets • Outlets • Soil stabilization				
3	Swales	**General considerations:** • Channel design • Slope	**Selection of siting:** • Service area • Plant type • Conditions for plant growth • Selection of media	**Regular inspections:** • Inspection of poor operation • Inspection of plant growth/ coverage • Inspection of sedimentation/ accumulation and compaction • Inspection of ponding • Inspection of inlets for sedi-ment accumulation	**Regular maintenance:** • Removal of debris and litter • Removal of sediment • Mowing • Plant clipping	• Dimension • Type of plant • Volume control • Peak flow control • Exceedance flow control	• Rain intensity • Flow • Soil moisture • Water quality
		Water quantity considerations: • Infiltration capacity • Depth of groundwater table	**Hydraulic design:** • Conveyance • Drainage/underdrain • Interception design • Peak flow control • Volume control • Exceedance flow design		**Remedial actions:** • Repair erosion by re-turfing or re-seeding • Channel repair • Mowing of top soil • Sediment removal		
		Water quality considerations: • Pretreatment • Pollution/contamination potential	**Physical construction requirements:** • Pre-treatment and inlets • Underdrain and outlets • Check dams • Gravel flow spreader • Flow divider				

Table 10.Solution specific issues for six NBS types extracted from CIRIA SuDS Manual (continued)

ID	Type of NBS	Planning	Design	Operation	Maintenance	Required documentation	Important/critical parameters
4	Bioretention systems	**General considerations:** • Service catchment/area • Ammenities of the bio-retention system	**Selection of siting:** • Infiltration capacity • Land use and ammenities	**Regular inspections:** • Inspection of poor operation • Inspection of filter media and establishement of appropriate replacement frequency • Inspection of sedimentation/ accumulation and removal frequency	**Regular maintenance:** • Removal of debris and litter • Removal of sediment/oil/ grease/floatable • Change of filter media	• Dimension • Substrate information (type, depth) • Roof gradient • Type of plant • Type of grey roof material • Volume control • Peak flow control • Exceedance flow control	• Rain intensity • Flow • Soil moisture • Temperature • Water quality
		Water quantity considerations: • Infiltration capacity • Depth of groundwater table • Bioretention/catchment ratio	**Hydraulic design:** • Peak flow control • Volume control • Exceedance flow • Water scour/internal erosion		**Remedial actions:** • Replacement of parts of infiltration structure		
		Water quality considerations: • Pretreatment • Pollution/contamination potential	**Physical construction requirements:** • Check dams • Pretreatment and inlet channels • Underdrain and outlets				
5	Pervious pavements	**General considerations:** • Ammenity • Pavement materials/options • Ground stability • Ground water table	**Selection of siting:** • Combination with other NBS • Soil classification • Landscape design and planting	**Regular inspections:** • Inspection of poor operation • Inspection of weed growth • Inspection of silt accumulation • Monitoring of inspection chambers	**Regular maintenance:** • Brushing and vacuuming (surface cleaning) • Soil stabilization/mowing • Removal of weeds	• Dimension • Layer information (type, depth) • Type of plant • Type of pavement material • Volume control • Peak flowcontrol • Exceedance flow control	• Water volume/flow • Rain intensity
		Water quantity considerations: • Systems of water management	**Hydraulic design:** • Infiltration rate • Peak flow control • Volume control • Exceedance control		**Remedial actions:** • Maintenance of landscape vegetation/soil • Rehabilitation of surface and upper substructure by sweeping		
		Water quality considerations: • Pollution/contamination potential • Sediment/silt load	**Physical construction requirements:** • Pavement construction/layer • Bearing ratio (CBR) • Traffic load • Design life time • Pretreatment and inlets • Outlets • Installment of geomembrane/ geotextile				

Table 10.Solution specific issues for six NBS types extracted from CIRIA SuDS Manual (continued)

ID	Type of NBS	Planning	Design	Operation	Maintenance	Required documentation	Important/critical parameters
6	Ponds and wetlands	**General considerations:** • Pond shape (to avoid dead zone) • Inlet and outlet design • Access route • Ammenity • Biodiversity	**Selection of siting:** • Ground stability • Wind mixing • Infiltration capacity • Ground water quality	**Regular inspections:** • Inspection of poor operation • Inspection of blockage/physical damage • Inspection of mechianical devices	**Regular maintenance:** • Removal of debris and litter • Sediment removal • Inspection of water quality • Vegetation control	• Dimension • Volume control • Peak flow control • Exceedance flow control	• Water volume/flow • Water level • Water quality
		Water quantity considerations: • Pond depth • Infiltration potential	**Hydraulic design:** • Design rain event • Interception/infiltration design • Peak flow control • Volume control • Exceedance flow		**Remedial actions:** • Repair erosion or other damage • Replanting • Pond aeration • Repair of inlets and outlets		
		Water quality considerations: • Stratification • Anoxic condition • Ground water infiltration • Pre/post treatment	**Physical construction requirements:** • Requirement for pre/post treatment • Sediment handling • Internal recirculation • Heat island effect				

5 Examples of data structure application

This chapter presents three examples of implementation of the data structure on two existing KLIMA2050 pilot plants and a commercial product from StormAqua (ALMA Raingarden). The aim is to provide the users of this guideline with some concrete illustrations on how to fill up the form and what information to include.

5.1 KLIMA2050 Pilot Høvringen – Greyroof

Table 11.Data structure applied to KLIMA2050 Greyroof Pilot in Høvringen

ID	Information required	Type of information	Documentation required	Description/input data
1	Name	Product/solution name		Høvringen pilot anlegg Greyroof
2	Type of NBS	Refer to https://ovase.no/wiki		Permeable/pervious pavement, greyroof
3	System Description	Description of the product/solution	Dimension	Non-vegetated roofs 8 × 11 m, • 2% longitudinal slope • Geotextile (sparasjonslag) • 200 mm LECA® LWA 1,5–2,5 mm • Belegningsstein (20 × 20cm)
			Volume control	Water holding capacity (WHC) of 26,2%
			Peak flow control	A peak runoff reduction of 95% (median) and for a peak delay of 1h and 15min (median)
			Exceedance flow control	Safe discharge
			Solution specific parameters	LECA® LWA is and expanded lightweight crushed clay aggregate with a bulk density of 500 kg/m3, a particle density of 1050 kg/m3, a particle size range of 1,5–2,5mm The weight of the LECA-based roof was calculated at 251 kg/m2 based on completely dry materials, and 310 kg/m2 for wet conditions (MWHC)
4	Planning	General considerations	Accessibility requirements	Maintenance access
			Management of drainage	Safe discharge to local drainage/sewer
			Maintenance skills,equipment and time input required	Minimum requirement
			Project phasing	None
			Expected performance	Detention: Water holding capacity (WHC) of 26,2%, 95% peak runoff reduction, over 1h peak delay Retention: 0,25 mm/day
			Solution specific issues	Handling of emergency overflow ie. Event excessing design slow
		Selection of siting	Exisiting water systems/ courses	Municipal sewerage system
			Potential overland flow/ infiltration issues	None
			Solution specific issues	

Table 11.Data structure applied to KLIMA2050 Greyroof Pilot in Høvringen (continued)

ID	Information required	Type of information	Documentation required	Description/input data
5	Design	Water quantity	Hydraulic design	Ksat 153.c cm/h, 2-year return period
			Peak flow control	Attenuation storage (can be calculated from Vladimir's data)
			Volume control	None (open drain channel to tipping weight scale)
			Exceedance flow	Gullies
			Solution dependent	Evaporation of 9% WHC
		Water quality	Impact on water quality	Yes, treatment effect may occur within the surface and subsurface matrices by filtration, adsorption, biodegradation, and sedimentation
			Discharge quality	No information available
			Solution dependent	
		Amenity (co-benefits)	Multi-functional use of space	Yes
			Reduction of heat-island effect	No
			Adaptability	Yes
			Recreational	No
			Bio-diversity	No
			Solution dependent	
		Data mangement	Monitoringof performance (Water quantity/quality/ amenity, etc)	Heated tipping bucket rain gauge (Lambrecht meteo GmbH 1518 H3, Lambrecht meteo GmbH, Göttingen, Germany) with a resolution of 0,1mm at 1-min intervals A CR1000 data logger (Campbell Scientific, Inc., Logan, UT, USA) recorded all the parameters at 1-min intervals
			Solution dependent	
		Sensor	Application of sensor(s) Goal, type, location	Weather station: Komplett værstasjon med 3x flyttbare vindmålere
			Monitoring of specific parameter(s)	Soil moisture: Decagon 5TM soil moisture and temperature sensors (in pavement media)
			Solution dependent	
6	Operation	Regular inspections	Type of action(s)	Observation of poor operation, weed growth, accumulation of sediment, also inspection chamber
			Frequency	Monthly, quarterly, up to yearly
			Procedure	Site visit, fill check-list
			Responsibility	Owner
			Data collection (type of data)	Flow, moisture, wind, rainfall
			Data assessments (O&M)	Site owner
			Solution specific issues	
7	Maintenance	Regular maintenance	Type of action(s)	Brushing/vacuuming
			Frequency	Yearly
			Procedure	Sweep over whole surface, pay particular attention to areas with sediment
			Responsibility	Site owner
			Solution specific issues	
		Remedial actions	Type of action(s)	Fixing landscape (i.e. level of paving), depression, broken blocks, etc. (as required)
			Procedure	Technician
			Responsibility	Site owner
8	Additional references	Refer to publication, brochures, etc.	Webpage	• http://www.klima2050.no/hovringen-bluegreengray-roofs • https://ovase.no/projects/4
			Scientific publication	• Hamouz, V, Lohne, J, Wood, J.R & Muthanna, T.M: Hydrological Performance of LECA-Based Roofs in Cold Climates. Water 2018, Vol. 10(3), p. 263; doi:10.3390/w10030263, ISSN 2073-4441 (Published online 3 March 2018)
			Report	• Elvebakk, K, Time, B, Skjeldrum, P.M & Kvande, T: Ombygging til blågrønne og blågrå tak. Problemstillinger og sjekklister. Klima 2050 Report 10. Trondheim, 2018. ISBN 978-82-536-1583-7

5.2 KLIMA2050 Pilot Høvringen – Greenroof

Table 12.Data structure applied to KLIMA2050 Greenroof Pilot in Høvringen

ID	Information required	Type of information	Documentation required	Description/input data
1	Name	Product/solution name		Høvringen pilot anlegg Greenroof
2	Type of NBS	Refer to https://ovase.no/wiki		Extensive greenroof
3	System Description	Description of the product/solution	Dimension	Vegetated roofs 8 × 11 m, • Sedum vegetation • 2% longitudinal slope • Soil thickness 30 mm • Berm height 500 mm • Drainage thickness 36 mm • Lightweight extruded clay aggregate layer 100mm
			Volume control	Water holding capacity (WHC) of 52,8% (Lab data Vladimir)
			Peak flow control	A peak runoff reduction of 99% (median) and for a peak delay of 17min (median)
			Exceedance flow control	Safe discharge to local drainage/sewer
			Solution specific parameters	Vegetation layer: Pre-grown reinforced extensive Sedum mat. Support layer: LECA® LWA expanded lightweight crushed clay aggregate with a bulk density of 500 kg/m3, a particle density of 1050 kg/m3, and a particle size range of 0–6mm
4	Planning	General considerations	Accessibility requirements	Maintenance access, plant establishment, vertilizer addition
			Management of drainage	Safe discharge to local drainage/sewer
			Maintenance skills,equipment and time input required	Minimum requirement
			Project phasing	None
			Expected performance	Detention: Water holding capacity (WHC) of 52,8%, 99% peak runoff reduction, 17,im peak delay (20 year return period, climate factor 1,4) Peak runoff: 0,6mm/min
			Solution specific issues	Handling of emergency overflow ie. Event excessing design slow. Water storage for irrigation
		Selection of siting	Exisiting water systems/ courses	Municipal sewerage system
			Potential overland flow/ infiltration issues	None
			Solution specific issues	Albedo, evapotranspiration, winter period
5	Design	Water quantity	Hydraulic design	Detention: Water holding capacity (WHC) of 52,8%, 99% peak runoff reduction, 17,im peak delay (20 year return period, climate factor 1,4) Peak runoff: 0,6mm/min
			Peak flow control	Attenuation storage (can be calculated from Vladimir's data)
			Volume control	None (open drain channel to tipping weight scale)
			Exceedance flow	Gullies
			Solution dependent	Evaporation of 9% WHC
		Water quality	Impact on water quality	Yes, treatment effect may occur within the surface and subsurface matrices by filtration, adsorption, biodegradation, and sedimentation
			Discharge quality	No information available
			Solution dependent	
		Amenity (co-benefits)	Multi-functional use of space	Yes
			Reduction of heat-island effect	Yes
			Adaptability	Yes
			Recreational	Yes
			Bio-diversity	Yes
			Solution dependent	
		Data mangement	Monitoringof performance (Water quantity/quality/ amenity, etc)	Heated tipping bucket rain gauge (Lambrecht meteo GmbH 1518 H3, Lambrecht meteo GmbH, Göttingen, Germany) with a resolution of 0,1mm at 1-min intervals A CR1000 data logger (Campbell Scientific, Inc., Logan, UT, USA) recorded all the parameters at 1-min intervals
			Solution dependent	
		Sensor	Application of sensor(s) Goal, type, location	Weather station: Komplett værstasjon med 3x flyttbare vindmålere
			Monitoring of specific parameter(s)	Soil moisture: Decagon 5TM soil moisture and temperature sensors (in pavement media)
			Solution dependent	

Table 12.Data structure applied to KLIMA2050 Greenroof Pilot in Høvringen (continued)

ID	Information required	Type of information	Documentation required	Description/input data
6	Operation	Regular inspections	Type of action(s)	• Inspection of soil substrate, vegetaion, drain • Inspection of soil substrate for erosion, channeling, and sedimentation • Inspection of inlets and drains for blockage • Inspection of leakage from the roof
			Frequency	Annualy, or after severe storm
			Procedure	Site visit, fill check-list
			Responsibility	Owner
			Data collection (type of data)	Flow, moisture, wind, rainfall
			Data assessments (O&M)	Site owner
			Solution specific issues	
7	Maintenance	Regular maintenance	Type of action(s)	• Removal of debris or litter • Replacement of dead plants • Removal of plant debris from decidous plant foilage • Removal of invasive vegetations/weeds • Mowing and clipping
			Frequency	Six-monthly or annualy
			Procedure	Manually or use tool if necessary
			Responsibility	Site owner
			Solution specific issues	
		Remedial actions	Type of action(s)	Resoil to fix channeling/erosionand trouble shoot the source of channeling (as required)
			Procedure	Technician?
			Responsibility	Site owner
8	Additional references	Refer to publication, brochures, etc.	Webpage	• http://www.klima2050.no/hovringen-bluegreengray-roofs • https://ovase.no/projects/4
			Scientific publication	• Johannessen, B.G: Investigating the use of extensive green roofs for reduction of stormwater runoff in cold and wet climates. Doctoral theses at NTNU, 2019:99, Norwegian University of Science and Technology, Faculty of Engineering, Department of Civil and Environmental Engineering. ISBN: 978-82-326-3796-3 • Johannessen, B.G, Muthanna, T.M & Braskerud, B.C: Detention and Retention Behavior of Four Extensive Green Roofs in Three Nordic Climate Zones. Water 2018, Vol. 10(6), p. 671; doi:10.3390/w10060671, ISSN 2073-4441 (Published online 23 May 2018) • Johannessen, B.G, Hanslin, H.M & Muthanna, T.M: Green roof performance potential in cold and wet regions. Ecological Engineering 2017, Vol. 106, Part A, p. 436-447; doi:10.1016/j.ecoleng.2017.06.011, ISSN 0925-8574 (Published online September 2017) • Hamouz V., Muthanna T.M. Hydrological modelling of green and grey roofs in cold climate with the SWMM model Journal of Environmental Management, Volume 249, 2019
			Report	• Elvebakk, K, Time, B, Skjeldrum, P.M & Kvande, T: Ombygging til blågrønne og blågrå tak. Problemstillinger og sjekklister. Klima 2050 Report 10. Trondheim, 2018. ISBN 978-82-536-1583-7

5.3 ALMA Raingarden – STORMAQUA

Table 13.Data structure applied to ALMA Raingarden

ID	Information required	Type of information	Documentation required	Description/input data
1	Name	Product/solution name		Alma Rain Garden (http://www.stormaqua.no/stormaqua document.aspx?nodeid=6873&docid=11304)
2	Type of NBS	Refer to https://ovase.no/wiki		Bioretention system
3	System Description	Description of the product/solution	Dimension	Three different sizes. For type 101, the dimensions are: Length: 1480 mm Width: 880 mm Height: 1500 mm
			Volume control	For type 101, the volumes are: Surface volume: 201 liter Sub-surface detention volume: 694 liter
			Peak flow control	• Ved småregn fungerer regnbedet som et vanlig bed hvor vannet kan trenge ned i grunnen. Det er plass til noe vann overvekstmediet, og dette vil gradvis infiltreres gjennom vekstmediet • Dersom det kommer mer vann enn det er plass til over vekstmediet, vil vannet renne ned til infiltra-sjons/fordrøyningskammeret gjennom et overløpsrør. Dette ivaretar også en vinterfunksjon.
			Exceedance flow control	• Dersom Alma regnbed er tilkoplet en sidestilt kum eller pukkmagasin, vil løsningen tilføre ekstra for-drøyningsvolum. • Dersom infiltrasjons/fordrøyningskammeret er fullt vil vannnivået på overflaten stige og vannet vil etterhvert renne som overløp til de omkringligg-ende oversvømmelsesarealer/regnbed.
			Solution specific parameters	Depending on the type of growth media and the invoming water, the rain garden may have a cleaning effect.
4	Planning	General considerations	Accessibility requirements	Access is required for maintenance
			Management of drainage	Safe discharge to local drainage/sewer in cases where the possibilities to infiltrate to the ground are insufficient. Overflow to surrounding overflow area.
			Maintenance skills,equipment and time input required	Minimum requirement. The raingarden is delivered with soil substrate and the necessary outflow volume control.
			Project phasing	None
			Expected performance	• Alma regnbed er et prefabrikert regnbed med ut-videt funksjon i forhold til et stedsbygget regnbed • Alma regnbed kommer i tre forskjellige størrelser som kan leveres med eller uten bunn • Et vannreservoir er innebygget. Det kan leveres med opptrekkskassetter for ekstra vanningskapasitet.
			Solution specific issues	Drainage can happen in two ways (or a combination of both): • Ved hjelp av infiltrasjon (der grunnforholdene ligger til rette for det) • Ved hjelp av utløp til offentlig nett eller øvrig overvannssystem (kan eventuelt være strupet)
		Selection of siting	Exisiting water systems/ courses	Municipal sewerage system
			Potential overland flow/ infiltration issues	None
			Solution specific issues	Alma regnbed kan motta regnvann fra taket via taknedløp, som ledes direkte inn i regnbedet. Vann fra omliggende arealer kan også ledes til regn-bedet ved hjelp av et rennesystem.
5	Design	Water quantity	Hydraulic design	Soil substrated constructed to requirements: Ksat: 3.06E-5 - 2.57E-4 Initial water content: 36% Soil density: 1.35 g/cm3
			Peak flow control	• Discharge of surface and subsurface detention volume can be to the sewer system or/and to the ground. Peak flow is controlled either by restriction to flow to the swer system or/and by the infiltration capacity to the ground. • When detention volume is full, peak flow is only restricted by the size and shape of surrounding overflow area
			Volume control	Type 101: Surface volume: 201 liter Sub-surface detention volume: 694 liter Overflow volume: According to design
			Exceedance flow	Flow rate limited by acceptable erosion of soil and robustness of plants.
			Solution dependent	• Ved småregn fungerer regnbedet som et vanlig bed hvor vannet kan trenge ned i grunnen. Det er plass til noe vann overvekstmediet, og dette vil gradvis infiltreres gjennom vekstmediet. • Dersom det kommer mer vann enn det er plass til, vil vannet renne ned til infiltrasjons/fordrøynings-kammeret gjennom et overløpsrør. Dette ivaretar også en vinterfunksjon

Table 13.Data structure applied to ALMA Raingarden (continued)

ID	Information required	Type of information	Documentation required	Description/input data
		Water quality	Impact on water quality	The soil substrate may act as a filter and have a cleaning effect on the runoff water.
			Discharge quality	The soil substrate may improve the quality of the runoff water
			Solution dependent	
		Amenity (co-benefits)	Multi-functional use of space	Yes
			Reduction of heat-island effect	Yes
			Adaptability	Yes
			Recreational	No
			Bio-diversity	No
			Solution dependent	• Can be integrated with an Urban Detention Roof, a green roof or a blue roof. This combination will detain runoff and increase the total performance. • Can add a green factor to the storm water manag-ement system for increased recreational benefit. • Can add biodiversity and cooling effect to heat island
		Data mangement	Monitoringof performance (Water quantity/quality/ amenity, etc)	As required
			Solution dependent	
		Sensor	Application of sensor(s) Goal, type, location	As required
			Monitoring of specific parameter(s)	As required
			Solution dependent	
6	Operation	Regular inspections	Type of action(s)	• Inspection of inlets and drains for blockage. • Inspection of soil substrate quality, vegetation drain • Inspection of soil substrate for erosion, channeling and clogging
			Frequency	Every six-month, or after severe storm
			Procedure	Site visit, fill check-list, refer to product manual
			Responsibility	Site owner
			Data collection (type of data)	Rainfall, flow, moisture content, wind
			Data assessments (O&M)	Site owner
			Solution specific issues	
7	Maintenance	Regular maintenance	Type of action(s)	• Removal of debris or litter • Replacement of dead plants • Removal of plant debris from decidous plant foilage • Removal of invasive vegetations/weeds • Mowing and clipping
			Frequency	Every six-month, refer to product manual
			Procedure	Manually or use tool if necessary
			Responsibility	Site owner
			Solution specific issues	
		Remedial actions	Type of action(s)	Resoil to fix channeling/erosionand trouble shoot the source of channeling (as required) or fix excess-ively clogged or poluted soil substrate.
			Procedure	Product manual
			Responsibility	Site owner
8	Additional references	Refer to publication, brochures, etc.	Webpage	• https://climateinnovationwindow.eu/innovations/alma-raingarden • http://www.stormaqua.no/stormaqua/document.aspx?nodeid=6873&docid=11304
			Scientific publication	• Sun, A:Hydrological modelling of Alma rain garden and concrete grid pavement". Master Thesesis. NTNU, Trondheim. 2019 • Kliewer, D: Runoff Modelling and thereon based Dimensioning of Stormwater Management Solutions: Raingarden and Detention Roof by Considering Norwegian Stormwater Management Practices. Master Thesis. FH Münster/Trondheim 2018 • Haugen, M., 2017. Funksjonsbeskrivelse og testing av prefabrikert regnbed som et hybrid naturbasert LOD tiltak (bachelor thesis). Universitetet i Stvanger - Teknisk-Naturvitenskapelige Fakultet, Stavanger.
			Report	-

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CONSORTIUM

Private sector

SKANSKA

MESTERGRUPPEN ARKITEKTER

Multiconsult

Finans Norge

SKJÆVELAND GRUPPEN

NORGESHUS

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AVINOR

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