Centre for Urban Greenery & Ecology
CUGE Standards

GUIDELINES ON **IRRIGATION FOR ROOFTOP GREENERY**

CS E06:2012

Guidelines on Skyrise Greenery

Published by:
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CUGE STANDARDS CS E06:2012

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The CUGE Standards Series is a set of published guidelines for adoption in the landscape and horticulture industry. They are written through a formal process that involves consultation with relevant bodies and reaching a consensus across all interested parties so that the final document meets the needs of business and industry. The standards take the form of either specifications, methods, vocabularies, codes of practices or guides.

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CS A Specifications on properties of planting media
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CS C Urban ecology
CS D Landscape design
CS E Skyrise greenery

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Irrigation for Rooftop Greenery

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The CUGE Standards will be reviewed every three years. Concurrently, CUGE also gathers new information continually through on-going research.

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Irrigation for Rooftop Greenery

SECTION 1 SCOPE

1.1 INTRODUCTION

This specification sets out the basic requirements for the design, construction and up-keep of the irrigation system of rooftop greenery.

1.2 OBJECTIVE

This specification is intended as a guide for the design, construction and up-keep of the irrigation system of rooftop greenery.

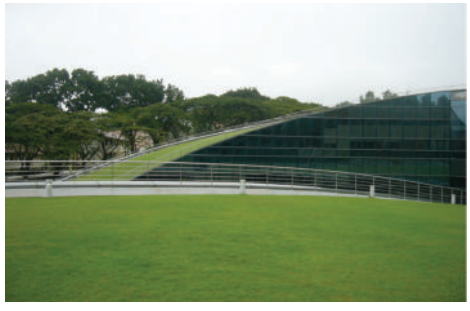
It is intended to act as a reference point for quality assurance of the irrigation system of rooftop greenery.

The design and construction of rooftop greenery shall comply with the relevant codes of practice and standards of the relevant authorities.

1.3 DEFINITIONS

Green roof

Extensive green roofs are generally not designed for active recreational use. They are developed mainly for aesthetic and ecological benefits. Distinguished for being low in installation cost, lightweight (90-150 kg/m^2) and with shallow mineral substrates, minimal maintenance is expected. Inspection should be performed, at the minimum, once or twice a year. Plants selected are usually of low maintenance and are self-generative. Extensive systems can also be placed on pitched roofs of up to an inclination of 30 degrees. They are common in European countries, especially Germany and increasingly being installed in North American cities as well.



Roof garden

Intensive green roofs, or roof gardens, are developed to be accessible. They are often used for recreation and other social activities. Hence they are associated with added weight, higher capital cost, more intensive planting and higher maintenance requirements. The plant selection ranges from ornamental lawn, shrubs, bushes to trees. As they are designed for usage, regular maintenance such as mowing, fertilising, watering and weeding is required.

1.4 PERFORMANCE REQUIREMENT

1.4.1 The irrigation system installed should achieve the following requirements:

- Support the long term performance of the green roof and/or roof garden.
- Achieve efficient use of water through proper irrigation scheduling and the use of appropriate controller.
- Do not compromise on the use or the aesthetic value of the green roof and/or roof garden.

1.4.2 Water conservation measures should be observed:

- Water plants in the early morning or late evening (between 4-7am or 6-9 pm) to minimise evaporation losses.
- Install private water meter at irrigation system to monitor consumption and leak detection.
- Encourage the use of WELs labelled fittings with minimum Very-Good-Rating.

1.4.3 Irrigation of rooftop greenery should use water efficiently. The following two design considerations can contribute to better irrigation efficiency:

- Drought tolerant plants
  Use drought tolerant plants for rooftop greenery. It is to be noted that general wind speed increases with altitude. Rate of moisture loss is increased, especially along the edges and corners of the green roofs and roof gardens. Drought tolerant plants are able to conserve water more effectively.

- Zone the plants (based on different watering needs)
  An array of plant species can be planted, and are planted on the rooftop of buildings. However, different plant species have differing needs. Some plants may need more sunlight, while others may need more water. It is thus advisable to group plants of similar needs in their respective conducive skyrise microclimate. This will allow the irrigation system design to be effectively zoned to meet the plants' requirements and use water efficiently.

SECTION 2 IRRIGATION SYSTEM

2.1 GENERAL CONSIDERATIONS

2.1.1 Vegetation establishment and growth on green roofs and roof gardens are very much influenced by the supply of water, specifically the quantity of water supplied and the frequency at which the water is supplied.

2.1.2 While some green roofs are designed without the need for an irrigation system, most roof gardens do require and are designed with irrigation system integrated. Whether or not an irrigation system is required for the green roof or roof garden depends on several factors, which include:

- The water demands of the selected plant species.
- The water storage capacity of the green roof or roof garden system, and the manner in which the stored water is accessed by the plants (for example, by evaporation, capillary action, or direct contact).
- The local rainfall patterns. Singapore receives about 2300 mm of rainfall each year, with the wet months generally occurring during November, December and January.

2.1.3 Most of modern day green roof and roof garden systems are engineered solutions that have built-in water storage capabilities. However the volume within these rooftop greenery systems for storage of water is limited by physical and economical considerations, which in turn are influenced by two important factors, namely:

- Design load of the rooftop greenery systems (and the load- bearing capacity of the rooftop structure)
- Overall depth of the rooftop greenery systems

2.1.4 In the design of green roofs and/or roof gardens, it is common to incline towards low design load and minimum overall depth of the green roof and/or roof garden systems. This usually translates into lower cost and lesser constraints on the construction of the green roof and/or roof garden. However, this leads to lesser volume for water storage within the green roof and/or roof garden systems for irrigation purposes.

2.1.5 The irrigation system is intended to ensure an appropriately consistent supply of water for healthy plant growth. Irrigation systems can be installed above, on or below the substrate surface of the green roof and/or roof garden systems.

Fig 1:
A typical drip-type irrigation system laid on the surface of the substrate of a green roof system.

2.1.6 The irrigation system can also be designed and planned with zonal control.

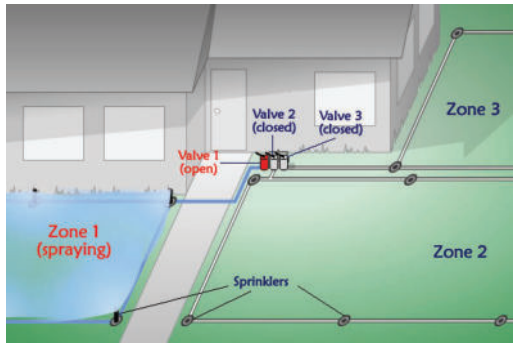


Fig 2:
An example of how the landscape irrigation system and layout can be zoned.

2.1.7 The irrigation system may be operated manually, semi- or fully automatic.

2.1.8 If potable water or NEWater is used, only manual system is allowed. For auto system, it should be manual turn-on and auto-shut. Fully automatic system (i.e. auto turn-on and turn-off) is not allowed unless devices like rain sensor and moisture sensor are incorporated at strategic locations to ensure no unnecessary watering. PUB's water conservation requirements are to be adhered to.

2.1.9 The irrigation system may be powered by AC electrical power supply or dry cell batteries that need to be replaced when their power supply is exhausted.

2.2 WATER SUPPLY METHODS

Timely water supply can be delivered manually or via automated system.

2.2.1 Manual irrigation

Manual watering tends to take more time, waste more water, and when inconsistently applied, it leaves areas of the rooftop greenery either over watered or under watered. A good automatic irrigation system solves most, if not all, of these problems.

Fig 3:
Manual watering on a roof garden through the use of a water hose with spring loaded nozzle incorporated.

Fig 4:
Sprinkler head of an automatic irrigation system when in operation.

2.2.2 Automatic irrigation

Automatic irrigation system can be accurately scheduled and timed, with monitoring of water usage. It is controlled via a central system and can be manned and monitored by one person. The automatic irrigation system can also be designed to irrigate the rooftop greenery by zones (customized to the irrigation needs of the selected vegetation). Accessorized components, such as rain-sensor and moisture detector, can also be incorporated to further improve efficiency of the automatic irrigation system.

However, an automatic irrigation system has the following disadvantages:

- A higher initial capital cost for materials, system and installation
- It requires regular maintenance (hence recurrent cost)

2.3 WATER STORAGE METHODS

2.3.1 Water can be stored in various components of the green roof and/or roof garden systems, and in a number of ways:

- Substrate
  Water can be stored in the substrate layer through the use of substrates that are designed to retain water. Additionally, water retention boards (such as rockwool and foam boards) or mats can be concealed within the substrate layer to enhance its water retention capacity.

- Substrate and drainage layer
  In addition to the substrate layer mentioned above, storage of water is increased through the drainage layer which uses open-pore water-retaining aggregate materials in graded granular sizes.

- Substrate and drainage-cum-reservoir layer
  In addition to the substrate layer mentioned above, storage of water is increased through the use of pre-formed drainage boards that conceive partial water retention features.

Fig 5:
The locations where water is stored within a typical extensive-type green roof system.

- Water retentive protective layer
  The use of water retention protective layers can provide additional water storage capacity.

2.3.2 Water may be stored simultaneously in the substrate and the underlayers mentioned above, irrespective of the type of rooftop greenery.

SECTION 3 TECHNICAL REQUIREMENTS OF IRRIGATION

3.1 WATER SUPPLY

3.1.1 Supply of water, where relevant, such as on a roof garden, should be adequate, consistent and appropriate for the selected plant species.

3.1.2 Delivery and spread of moisture to the plant species should preferably be even. An even spread of moisture can be achieved through appropriate spacing and layout of irrigation pipes. (The irrigation specialist and/or the landscape consultant will be able to advice.)

3.1.3 Plant roots are attracted to sources of moisture such as the drip holes of irrigation pipes installed within the substrate. Plant roots clogging up the drip holes are not uncommon, and may adversely affect the quality of the irrigation. As such, drip irrigation piping should preferably have design provision to counter plant-root penetration.

3.2 WATER STORAGE

3.2.1 Reference publications:

- Please refer to CS E03: Substrate section 3.6, Water storage abillity / Maximum water storage capacity
- Please refer to CS E04: Drainage section 3.3.5, Water storage capacity

3.3 GREEN ROOF

- For green roofs, water supply is generally from rainfall.
- Water storage can be via the substrate layer, drainage-cum-reservoir layer, moisture retention/protection layer, or a combination of these materials.
- However, there should be a water-supply or tap point at the green roof as a contingency against prolonged drought that may adversely affect plant health. (In the situation where clean potable water is urgently required, such as for cleaning purposes during maintenance work.)

3.4 ROOF GARDEN

- Water supply is generally via a supply line or point that may be manually operated, semi- or fully automated.
- It can be in the form of sprinkler system, above-substrate or below-substrate drip system.
- Water storage is generally via the substrate. However, when installed, the drainage-cum-reservoir layer and/or moisture retention/protection layer can contribute to water storage too.

3.5 PITCHED GREEN ROOF

- Water supply is generally via supply line or point that is semi- or fully automated.
- Manually irrigating pitched green roof is not encouraged because of personal safety reasons. Depending on the degree of pitch or slope, which corresponds to difficulty in maneuvering on the green roof, manual irrigation should not be considered.
- Water storage and retention on a pitched green roof is constrained by the natural movement of water down the slope. This can leave the upper half of the roof extremely dry, while water collects or drains off in the lower half. If balanced water storage in the medium is desired, the reservoir layers, moisture retention layers and media constraining battens will need to be designed to inhibit water from flowing directly down the slope.

3.6 IRRIGATION FREQUENCY AND REQUIREMENT

3.6.1 Irrigation requirement for rooftop greenery is heavily dependent on design and material selection. The onus is on the building owner and end user to optimize water consumption. The following figures are indicative.

Types of rooftop greenery	Categories of vegetation	Estimated water requirement (l/sqm/day)
Green roof	Low, hardy ground-covering plants	up to 4
Roof garden	Trees and Palms	20
	Shrubs	up to 8
	Ground covering plants	4
	Turf, lawn or grass	up to 10

3.6.2 Unlike roof gardens, green roofs are designed to depend primarily on natural rainfall for their water needs; this being available without cost. This also minimizes the need for supplementary or external watering, and helps to return the rain water back to the natural water cycle quickly.

3.6.3 For pitched green roofs, especially those steep ones, external irrigation sources should be provided to avoid plant withering and also, the possibility of erosion.

3.7 ADDITIONAL IRRIGATION

3.7.1 Additional irrigation is required only when the green roof and/or roof garden systems, with their built-in water storage capabilities, are not adequate in meeting the water requirement for a certain time-window as mentioned above.

3.7.2 The source of the additional irrigation is not to be confused with the fire hose reel which may be installed at the roof but not meant for irrigation purposes. There should be at least one tap point at the roof in the vicinity of the rooftop greenery.

3.7.3 Additional irrigation may be provided by using:

- Water hose connected to a tap point, with spring loaded nozzle incorporated
- Hose and portable sprinkler
- Spray hoses
- Drip irrigation lines
- Overhead irrigation system
- Automated irrigation systems with an in-built reservoir

3.7.4 Except for water hose and hose & sprinkler, the other systems can either be operated manually or controlled by means of a timer.

3.7.5 A hand-held water hose that is connected to a tap point can be used to water any area that cannot be reached by a sprinkler system, such as the edges, corners, or other odd areas.

3.8 SPRINKLER-IRRIGATION REQUIREMENT

A sprinkler system contains a few main components:

3.8.1 The controller - This is an electronic, computerized unit that normally fastened on an elevated level on the wall or a vertical surface within or near the rooftop greenery. It is the "Mastermind" behind the sprinkler system, and together with a build-in timer, it instructs the rest of the irrigation system the right time to turn on the correct set of sprinkler heads for the right irrigation duration. The controller is connected to a set of valves that regulate the flow of water into a specific "zone" in the sprinkler system.

3.8.2 The valves – The valves act like "doors" or "gateways" that turn off and on when instructed by the "Mastermind", which is the controller. The valves are connected directly to the irrigation system and are normally found in buried or half-buried plastic boxes with removable lids for access.

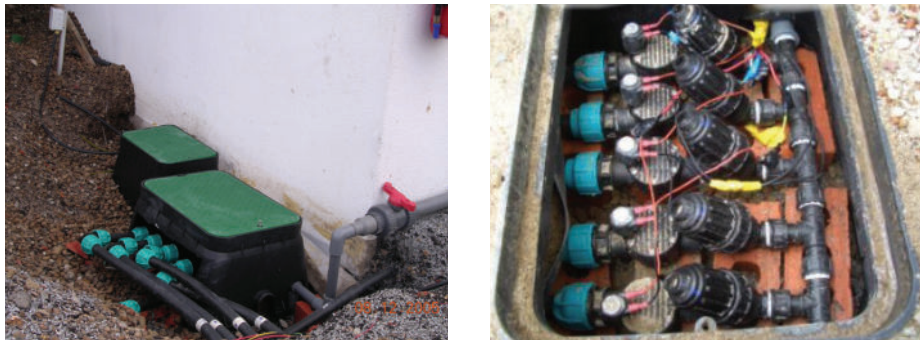


Fig 6:
A typical valve chamber in a semi-buried box (left pic) and the valves inside the chamber (right pic).

3.8.3 The pipes – The valves feed water into the rest of the sprinkler system, which comprise of plastic PVC pipes that lead to the sprinkler heads. The pipes are usually buried within the substrate.

3.8.4 The sprinkler heads – There are typically 2 types of sprinkler heads – the "pop-up" heads and the "raised" heads.

- The former type is normally installed at about the ground level when not in use,and pops-up when the water pressure fills the pipes below them.

Fig 7:
A typical pop-up sprinkler head when not in use (left pic) and when in operation (right pic).

- Raised heads are also used in garden areas, where they are permanently elevated above the surrounding foliage and thus are able to deliver water without being blocked by other plants.

Fig 8:
A permanently raised sprinkler head.

3.8.5 Accessories – There are some extra items, like rain sensors and moisture sensors that will keep the irrigation system from running on rainy days.

Fig 9:
A common rain sensor, an accessory of an irrigation system.

3.9 DRIP-IRRIGATION REQUIREMENT

3.9.1 A drip irrigation system works by channeling water through a series of pipes that are laid on the surface of the substrate and have tiny holes at fixed intervals along the length of each pipe. The water then flows out of the holes directly to the substrate and is absorbed by the roots of the plants.

Fig 10:
A typical controller of a drip irrigation system

Fig 11:
A close-up view of the drip line and the tiny hole through which water drips onto the substrate and is absorbed by the roots of the plants.

3.9.2 The main advantages with this method are as follow:

- The water can be released at close proximity to the root of the plants and so minimal water is wasted.
- There is better control over the amount of water released to the plant.

3.9.3 This type of irrigation is exceptionally advantageous for plants that are very sensitive to the amount of moisture provided. For some plants, too much water or too little water can be undesirable to their growth patterns.

3.9.4 Drip Irrigation can be scheduled via the controller to keep the substrate adequately moist, which protects the substrate against erosion. Organic nutrients can also be directly fed to the plants through the automated irrigation system, via an installed fertigator system. These promote plant growth, which further stabilizes the substrate.

3.9.5 All irrigation systems of whatever type require regular inspections to ensure the pipes are properly connected and the emitters are not clogged or blocked, infested with roots or insects, algae and fungus, and mechanisms are functioning and not damaged by garden tools or other hostile access. Incorrect installation and lack of regular maintenance will adversely affect plant growth and result in unsatisfactory visual effects. Mandatory irrigation audit by an independent irrigation auditor should be conducted periodically to ensure the irrigation system is in good working order.

3.10 RAINWATER HARVESTING

3.10.1 With relevant engineering input, green roofs and roof gardens can also be holistically designed to contribute to the rainwater harvesting system. The collected rainwater can be used to supplement the irrigation needs. It is to be noted, that rainwater harvested from green roofs and/or roof garden is non-potable.

3.10.2 To prevent the unwitting use of the harvested rainwater for potable purposes, it is to be clearly displayed at the points of use the label "non-potable use only/not for drinking".

3.10.3 Developers who would like to build rainwater harvesting systems and underground tanks to collect rainwater in their premises for their own non-potable uses, will have to comply with Singapore Public Utilities Board (PUB) requirements. Please refer to the following links for the general guidelines on rainwater harvesting:

http://www.pub.gov.sg/conserve/ProductsSolutions/Pages/AltSrcWater.aspx

3.10.4 Rain water harvesting system is recognized under PUB's ABC Waters Certification Scheme. Developers and professionals may refer to the following link for details:

http://www.pub.gov.sg/abcwaters/abccertified/Pages/default.aspx

3.11 GUIDELINES ON MOSQUITO PREVENTION IN RAINWATER COLLECTION SYSTEM FOR NON-POTABLE USE BY NEA

3.11.1 From the perspective of mosquito-breeding prevention, NEA published the following guidelines pertaining water collection systems on Sep 2010. It focuses on 2 areas:

1) Catchment areas - Rooftop greenery, whether a green roof or roof garden, falls into this category. The NEA guidelines centre on eliminating any possibility of stagnant water collection during the design stage. The factors for consideration include:
   - Gradient or slope
   - Drainage system serving the rooftop greenery
   - Possibility of leaves and branches that may clog up the drainage system.

2) Rainwater conveyance– This refers to the journey through which rainwater is transported. Whether through gutters and/or downpipes, the NEA guidelines centre on having a clog-free journey that can also be easily accessed, inspected and maintained.

3) Storage tank - The rainwater collection tank is to be mosquito-proof in accordance to NEA's Guidelines on Mosquito prevention in domestic rainwater collection system for non-portable uses. Please refer to the following link:

http://www.nea.gov.sg/cms/ehd/Guidelines_on_RainwaterCollectionSystem.pdf

3.11.2 The Qualified Person (QP) is required to submit the structural plans of green roofs and roof gardens to NEA for comments on mosquito-proofing measures required.

3.12 MONTHLY RAINFALL IN SINGAPORE

For calculation of irrigation water supply from rainfall in Singapore, it is necessary to check with NEA (National Environment Agency) Singapore on the current rainfall data. The data may be useful for the planning and design of irrigation systems and storm water management systems.

3.13 EVAPO-TRANSPIRATION

3.13.1 Evapo-transpiration (ET) is a collective term for the transfer of water, as water vapour, to the atmosphere from both vegetated and un-vegetated land surfaces. It is affected by climate, availability of water and vegetation. This transfer of water vapour back into the atmosphere helps to cool the rooftop surface.

3.13.2 While climate is an 'uncontrollable' factor, availability of water (which is closely linked to water storage capacity of the green roof and roof garden systems) and vegetation can be up-kept in order to achieve optimum evapo-transpiration. After all, cooling the rooftop surface is a primary objective of having rooftop greenery.

3.14 QUALITY OF INSTALLATION

The basic "Best Practices" guidelines in ensuring that the irrigation system is properly installed are as follow:

1) Identify and select the irrigation system to meet the design criteria.

2) Contract with a licensed, experienced and reputable irrigation professional to complete the installation.

3) Before commencing installation, verify that water tap, flow rate and pressure meet design criteria.

4) Ensure that the site drainage has not been altered for existing plant communities that are not planned to receive supplemental irrigation.

5) Install the irrigation system's components according to the design specifications and manufacturer's published performance standards.

6) Where deviations from the design are required (e.g., running pipe around a tree or other structure or adding sprinkler heads to an area larger than the plan shows), consult with the irrigation professional prior to making the change to ensure that the change is within design performance specifications.

7) Enforce regular site inspections during system installation to check for adherence to the design. The purpose of the inspections is to check for proper installation and function of the backflow prevention assembly, main line, pipes, valves, sprinkler heads, control wire, controller and water conserving devices.

8) Furnish "As-built" record drawings to the Owner of the irrigation system. The record drawings should describe the system layout and components including all changes from the original design.

9) Test out or commission the irrigation system to verify that the system meets the design criteria. Create an irrigation schedule to meet the needs of the plants. Review the irrigation schedule regularly, specifically its rationale and how to set irrigation days, zone run times and start times.

10) Review advanced programming features such as multi-cycle irrigation to prevent run-off and the use of the percentage water increase/decrease function.

11) Explain to the end user (or Owner) the location and operation of the controller, valves, sensors, pressure regulators, backflow prevention device and sprinkler heads. Educate the owner on features and capabilities of the system including the maintenance requirements.

12) Provide the end user (or Owner) with recommendations for landscape water conservation.

13) Provide the end user (or Owner) with product warranties and operating instructions for all equipment.

14) Ensure the end user (or Owner) understand the function and operation of other accessories and devices such as the rain sensor, substrate moisture sensor, fertigator, etc.

3.15 REFERENCE STANDARDS / ARTICLES / PUBLICATIONS

3.15.1 ASTM F690-86(2003) - Standard Practice for Underground Installation of Thermoplastic Pressure Piping Irrigation Systems

3.15.2 BS 7562-3:1995 - Planning, design and installation of irrigation schemes – Part 3: Guide to irrigation water requirements.

3.15.3 BS EN 12484-4:2002 - Irrigation techniques. Automatic turf irrigation systems. Installation and acceptance

3.15.4 BS EN 13997:2003 - Irrigation techniques. Connection and control accessories for use in irrigation systems. Technical characteristics and testing

3.15.5 BS EN 15099-1:2007 – Irrigation techniques. Remote monitoring and control for irrigation systems. General considerations

3.15.6 Dr Tan P.Y. and Sia A. (March 2009). Nature in Singapore 2009 by NUS: article Understanding The Performance of Plants on Non-Irrigated Green Roofs in Singapore Using Bio-Mass Yield Approach. Singapore.

3.15.7 Castletona H.F., Stovin V., Beck S.B.M., Davison J.B. (2010). Energy and Buildings 2010: article Green roofs; building energy savings and the potential for retrofit.

3.15.8 Green Roof Organisation. (2011). The GRO Green Roof Code: Green Roof Code of Best Practice for the UK 2011.UK.

3.15.9 National Environment Agency Singapore. Weather Wise Singapore. http://app2.nea.gov.sg/data/cmsresource/20090324939502642695.pdf.