Water Sensitive Urban Design

Water Sensitive Urban Design (WSUD) is an approach to urban planning and design that integrates the management of the total water cycle into the urban development process. It includes:

- Integrated management of groundwater, surface runoff (including stormwater), drinking water and wastewater to protect water related environmental, recreational and cultural values;
- Storage, treatment and beneficial use of runoff;
- Treatment and reuse of wastewater;
- Using vegetation for treatment purposes, water efficient landscaping and enhancing biodiversity; and
- Utilising water saving measures within and outside domestic, commercial, industrial and institutional premises to minimise requirements for drinking and non drinking water supplies.

Therefore, WSUD incorporates all water resources, including surface water, groundwater, urban and roof runoff and wastewater.
Acknowledgments

Funding for preparation of the Water Sensitive Urban Design Technical Manual for the Greater Adelaide Region was provided by the Australian Government and the South Australian Government with support from the Local Government Association (SA).

The project partners gratefully acknowledge all persons and organisations that provided comments, suggestions and photographic material.

In particular, it is acknowledged that material was sourced and adapted from existing documents locally and interstate.

Overall Project Management
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Steering Committee
A group of local government, industry and agency representatives provided input and feedback during preparation of the Technical Manual. This group included representatives from:

- Adelaide and Mt Lofty Ranges Natural Resources Management Board;
- Australian Water Association (AWA);
- Department for Transport, Energy and Infrastructure (DTEI);
- Department of Water, Land and Biodiversity Conservation (DWLBC);
- Environment Protection Authority (EPA);
- Housing Industry Association (HIA);
- Local Government Association (LGA);
- Department of Planning and Local Government (DPLG);
- South Australian Murray-Darling Basin Natural Resources Management Board;
- South Australian Water Corporation;
- Stormwater Industry Association (SIA); and
- Urban Development Institute of Australia (UDIA).

Technical Sub Committee
A technical sub committee, chaired by Dr David Kemp (DTEI), reviewed the technical and scientific aspects of the Technical Manual during development. This group included representatives from:

- Adelaide and Mt Lofty Ranges Natural Resources Management Board;
- City of Salisbury;
- Department for Transport, Energy and Infrastructure (DTEI);
- Department of Health;
- Department of Water, Land and Biodiversity Conservation;
- Department of Planning and Local Government; and
- Urban Development Institute of Australia.

From July 2010, DWLBC was disbanded and its responsibilities allocated to the newly created Department For Water (DFW) and the Department of Environment and Natural Resources (DENR).

Specialist consultant team
Dr Kylie Hyde (Australian Water Environments) was the project manager for a consultant team engaged for its specialist expertise and experience in water resources management, to prepare the Technical Manual.

This team comprised Australian Water Environments, the University of South Australia, Wayne Phillips and Associates and QED Pty Ltd.

Beecham and Associates prepared Chapter 16 of the Technical Manual.
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Appendices

Appendix A  Baseline Water Quality Data
Chapter 16
Siphonic Roofwater Systems

16.1 Overview

An important functional requirement of many Water Sensitive Urban Design (WSUD) systems is to harvest and reuse runoff collected from roofs, roads and other urban catchment surfaces. This often becomes a challenge in highly developed residential, commercial and industrial areas due to space constraints and due to the general increased size of buildings. It is therefore little surprise that on walking through the central business district (CBD) of Adelaide it is very hard to find a rainwater tank, let alone a sophisticated stormwater reuse system. This is partly because of the limited space available to site rainwater tanks but it is also partly because of the difficulty of collecting the water discharging from the large number of downpipes that typically surround a building in the CBD.

The reason why apartment buildings and commercial and industrial buildings have a large number of downpipes is that most conventional roof drainage systems discharge under gravity flow conditions. This is a very inefficient way to drain water from a gutter system and indeed the pressure head driving the flow is only the few millimeters of water depth in the gutter, irrespective of the height of the building.
There is however a relatively new way of harvesting water from large roof surfaces. Siphonic roofwater harvesting systems utilize the height of the building to create negative pressures in the pipework. This allows the system to suck water out of the gutters at high velocities and flowrates. Because the system flows under pressure, the majority of the pipework can be horizontal rather than vertical and there is also a greatly reduced number of downpipes – quite often only one or two. This means that there is only need for one or two rainwater tanks for storing the harvested water. In addition these tanks which are often modular in design, can be installed inside the building in any under-utilised space such as under a stairwell.

Therefore siphonic roofwater systems and their associated storage and reuse systems offer a new and efficient way to implement WSUD in highly urbanized environments.

This chapter of the Technical Manual for the Greater Adelaide Region is aimed at providing an overview of siphonic roofwater harvesting systems and how they can assist in achieving the objectives and targets of WSUD.
Description

Siphonic systems are a relatively recent innovation in roof and building drainage design. Many eminent buildings utilise siphonic systems, including the Adelaide Convention Centre as well as both the Federation Square and Docklands developments in Melbourne. Siphonic systems are also widely used in sports stadia such as Sydney’s Stadium Australia, the Sydney Cricket Ground, the MCG and the North Stand at AAMI Stadium in Adelaide. Many new airport terminal buildings including those in Hong Kong, Kuala Lumpur, Sydney and Adelaide also have this type of roof drainage system (Figure 16.2).

Since siphonic systems may be used on any building over approximately 4.5m in height, they can readily be implemented on medium to high density, multi storey residential buildings. For example, a siphonic roofwater system is an integral part of the new Altitude at the Precinct residential tower building in Morphett Street, Adelaide. Siphonic systems are also being employed at the commercial property development at 400 King William Street, Adelaide and at the four storey building at 66 Rundle Street, Kent Town.

Conventional roof drainage systems collect water in box, eave or valley gutters and remove that water using freely discharging downpipes that are designed to flow up to a maximum of one third full under the action of gravity. For large roof surfaces this can result in numerous downpipes (see Figure 16.3) that are relatively large in cross-section. The head of water driving the flow is often only the depth of water in the gutter or box receiver. For a flat roof surface with no gutters the driving head may only be of the order of 30 mm (May, 1995).
Figure 16.2 Siphonic Buildings (Clockwise from Top): Federation Square in Melbourne; Stadium Australia; the Melbourne Cricket Ground; and North Stand at AAMI Stadium, Adelaide

Source: Courtesy of Syfon Systems P/L
In contrast, siphonic systems are designed to exclude air from the pipework and, once primed, cause the pipes to flow under pressure (Figure 16.4). A major advantage of siphonic systems is the greatly increased driving head of water and consequent reduced need for vertical pipework. The driving head in this case is effectively the difference in level between the water in the gutter and discharge point, which is usually near ground level.

A further advantage is that because the pipes operate under full-bore conditions, the pipe sizes may be reduced substantially. May (1995), estimates that for the simple case of an outlet with a given diameter of vertical downpipe, a siphonic system would have approximately ten times the flowrate capacity of a conventional gravity system.
Siphonic roofwater harvesting systems use no electric pumps for harvesting roofwater. It is important to note though that the advantages of siphonic systems only become evident in buildings that have roofs higher than approximately 4.5 m above ground level. This is because it is this height that drives the flow through the pipe system.

Figure 16.5 shows the main components of a typical siphonic roof drainage system, which are:

- Siphonic outlets
- Box gutters
- Siphonic pipe system
- In-ground drainage system

**Purpose**

All siphon systems operate passively, in that they are primed solely by an increasing water depth in the gutter. There are no pumps or other electric systems. Once primed, the pipes within the system discharge full bore.

Once primed, siphonic systems operate much like domestic water supply systems and therefore the pipework does not need to be mostly vertical as we are used to seeing in domestic roof applications. Indeed most of the pipework in siphonic systems is horizontal and so this can be incorporated in the space just below the roof surface as shown in Figure 16.6.
Figure 16.6: Horizontal Collector Pipe at AAMI Stadium in Adelaide

This horizontal pipework is usually suspended on a bracketed support system as shown in Figure 16.6. These horizontal collector pipes are used to bring all roofwater flows together at one or two strategically placed downpipes, from where the runoff can be harvested into storage tanks. In this way siphonic systems provide a sustainable solution to harvesting water from multi storey residential and large commercial and industrial buildings.

Scale and Application

The typical application scale for siphonic roofwater harvesting systems is the property (building) and street (precinct) scale. In either case, it is often possible with siphonic systems to harvest 100% of the rainwater falling on the roof system. This often requires significant storage systems to be incorporated into the design. Figure 16.7 shows the large rainwater tank needed for the siphonic system at the Bianco warehouse at Gepps Cross.
Figure 16.7  Rainwater Tank at the Bianco Warehouse at Gepps Cross
16.2 Legislative Requirements and Approvals

All siphonic systems should be designed to satisfy *AS 3500 Part 3.1: Stormwater drainage*. However, other Australian standards include:

- AS4130 – Metric Pipe
- AS2033 – Installation of Polyethylene. Pipe Systems
- AS2180 – Metal Rainwater Goods

Before undertaking a concept design of a siphonic roofwater harvesting system it is important to check whether there are any planning regulations, building regulations or local health requirements that apply to such systems in your area.

The legislation which is most applicable to the design and installation of siphonic roof drainage systems in the Greater Adelaide Region includes:

- Development Act 1993; and

A thorough investigation of required permits and approvals should be undertaken as part of the conceptual design of any siphonic roofwater harvesting system.

To find out further information regarding legislative requirements and approvals, please consult with your local council.
16.3 Design Considerations

The following design considerations should be used when the installation of a siphonic roofwater harvesting is proposed.

**General**

The design for the system should be in accordance with Australian Standard AS3500.3.2 for all roof areas. The whole of the roof drainage system should be provided with a 100% overflow system.

The calculations for the size and position of roof gutter siphonic inlets, horizontal and vertical pipework including bends, branches, junctions and their connections to any associated underground pipework should be prepared by an approved siphonic specialist. These calculations should be based on detailed architectural and hydraulic engineering drawings of the project together with the design rainfall intensity.

The pipework system should be sized to convey the design roof water flow from the siphonic inlets through the system to the point(s) of discharge in the most efficient possible direction. The minimum velocity should be 1.0 m/s for self-cleansing purposes. The maximum negative pressure in the system should not exceed 8.0m in water head in order to avoid potential cavitation effects.

**Pipework**

All pipe and fittings should be HDPE, PN4 or greater or other approved material manufactured in accordance with AS4130 (or equivalent) and installed generally in accordance with AS2033.

All HDPE pipework and fitting joints, prepared during the fabrication phase, should be butt fusion joints, utilising approved butt fusion welding equipment under factory controlled conditions.

All joints should be either butt fusion welds utilising approved butt fusion welding equipment or electro-fusion sleeves installed strictly in accordance with the manufacturer’s instructions or hot air welds undertaken by accredited welders or using a proprietary flanged jointing system.

**Inlets**

Inlets supplied by the siphonic contractor should be installed into the gutter by the roofing contractor.

All siphonic inlets for the collection and discharge of the surface water from the roof should be siphonic roof inlets incorporating leafguards when installed in box gutters.
Siphonic inlet bodies should be stainless steel. The inlet body should be fixed generally in accordance with AS2179.

Siphonic inlet should be fitted with baffles designed to restrict the entry of air to the system and these should be made of a durable material. The leafguard should be fitted to gutter siphonic inlets and should be designed to restrict the entry of debris into the system without unduly restricting the flow. The leafguard should be made of a durable material.

All inlets to be self-priming to avoid a build-up of water within the gutter system.

**Support System**

The collecting mains and downpipes should be supported generally in accordance with the intent of AS2180. The pipework support system should take into account the following:

- Weight of pipe and water
- Vibrations
- Thrust forces

Typically with HDPE pipe systems, the pipe support system is a continuous galvanized rail system. Since HDPE pipes have some lateral flexibility this support system maintains the pipes in straight lines and prevents buckling from internal water forces.

Pipes and fittings should be securely suspended from the suspension rail by means of purpose made and fixed anchor pipe clamps.

Pipe clamps should be fixed so as to restrict the effects of thermal expansion and contraction of the pipework and to allow for any water hammer that may occur. Extra restraints may be required at changes of direction in the main lines to prevent any movement of the pipe.

Generally pipe clamps are fitted at each side of branch connections and at no more than 10 times the pipe diameter on the collection mains. Vertical pipework should be rigidly fixed to the building structure with pipe clamps not more than ten times the pipe diameter.

**Installation**

The siphonic system should be installed only by fully trained and qualified personnel employed directly by the siphonic roof drainage contractor. All installers should be registered plumbers.
Acoustics

Acoustic treatment to piping may be required in accordance with the acoustic engineer’s requirements.

Connection to In-ground Pipe

The completed siphonic system should be connected to a rainwater tank with sufficient overflow relief. This should be installed by the civil contractor with an appropriate seal to the HDPE pipe.

Maintenance

Due to the high velocities generated within the siphonic roof drainage system the pipes are generally self-cleansing. The self-cleansing process means that the system requires only a minimum amount of maintenance under normal conditions. However, a routine maintenance schedule should be undertaken to ensure the system is working at optimum efficiency. The frequency of the system maintenance will depend on the site conditions, and maintenance procedures should be timed to suit. In areas with deciduous trees, gutter cleaning should take place during and after the autumn months. The entire system should also be checked at the time of year when the most severe storm events are expected.
16.4 Design Process

Overview

The design of siphonic roof drainage systems typically follows the following procedure:

- Determination of the maximum design flowrate from the roof catchment surfaces
- Determination of number of siphonic outlets needed
- Determination of optimum outlet spacing and pipe lengths
- Design of collector pipe and tailpipe configurations
- Hydraulic balancing of pipes and tailpipes to available disposable head

These steps are explained in the following sections.

Maximum Design Flowrate

The main purpose of any roof drainage system is to convey the runoff from the roof and gutters safely to ground level and protect the building and its contents from water damage. A roof drainage system design must achieve a reasonable balance between the cost of the system and the probability and consequences of structural failure or flooding (ASPE, 2006).

The design flow for a roof depends on the average recurrence interval (ARI) for a particular duration and the statistical rainfall intensity $I$. The minimum values of these are normally stipulated by local Councils or other authorities. The general ARI used in the design of siphonic roof drainage in Australia is the 100 year, 5 minute storm. Usually these values are calculated using the method described in Australian Rainfall and Runoff (1987).

A useful program called AUS-IFD Version 2.0 has been developed by Dr Graham A. Jenkins which calculates the design average rainfall intensities and temporal patterns for most locations in Australia using the procedures described in Australian Rainfall and Runoff, 1987. It is available at the following website:

www.ens.gu.edu.au/eve/Research/AusIfd/AusIfdVer2.htm

By using the AUS-IFD Version 2.0 program, we can identify the rainfall intensity to be used in the design flow calculations. An example of the program output is shown in Figure 16.8 for the rainfall intensity of a 5 minute duration, 100 year storm in Adelaide.
Once we have the design rainfall intensity, we can calculate the design flow by determining the roof area to be drained by each gutter. This is achieved by simply multiplying the roof area by the design rainfall intensity.

**Number of siphonic outlets**

The number of outlets needed for each gutter system is determined according to the maximum flowrate that each outlet can accommodate. These values are available from the manufacturers. Siphonic outlet manufacturers usually produce different outlets which have various flow capacities such as 10, 15 or 25 litres per second (Figure 16.9).
Determination of Outlet Spacing and Pipe Lengths

A study by Bramhall and Saul (1998), on siphonic roof drainage systems identified that the positioning of the siphonic outlets plays a significant role in the height of water in the gutter. They recommend that outlets be placed equidistant along the gutter for optimum performance. For example, as shown in Figure 16.10, in a box gutter system that has seven outlets and is 118m long, the outlet spacing should ideally be:

\[
118 / 7 = 16.85 \text{m}
\]

This ensures that the same area of roof is draining to each outlet. If each outlet was rated with a 15 L/s capacity, the ideal flowrates for this roof and gutter system would be as shown in Figure 16.11.
Design of Collector Pipe and Tailpipe Configurations

Once the outlet spacing has been established, the general layout of the pipework is configured. This should be ideally done in conjunction with the architect or designer at the design stage. The pipe layout depends on many design variables such as the available space restrictions and placement of the horizontal collector pipework. The connection point into the underground drainage system is also an important consideration.

The velocity of the water flow in the pipework is a very important variable in the performance of siphonic roof drainage systems. Friction and form losses increase significantly as flow velocity increases so the correct choice of pipe sizes is crucial in the design of the systems.

Pipe sizing is determined from computer analysis programs and is the domain of the siphonic designer. Figure 16.12 shows a schematic of the Adelaide Airport siphonic system as generated from the design software program used on this project. This is an unusual siphonic system since it has multiple downpipes. This design decision was mainly for architectural and aesthetic reasons.
Typical pipe sizes generally range from 50mm to 315mm in diameter. These sizes vary depending on the position in the system and the size of the catchment areas. Preliminary pipe sizing should be undertaken in consultation with a siphonic drainage designer with the required information being:

- The roof area
- The roof construction
- The rainfall intensity
- The height of the building
- Indication of preferred pipe routing
- Conditions inside the building - temperature
- Indication of preferred piping material
- Location of any expansion provision

With the pipe sizes determined, allowances should be made in the building structure for the weight of the pipe and support system under full flow conditions. For example a 315mm diameter HDPE pipe full of water and including the support system can weigh approximately 80kg/m length of pipe.
Balancing Siphonic Drainage Systems

Once the general layout of the system has been decided, hydraulic balancing process is undertaken. The purpose of balancing the siphonic pipe system is to ensure that the driving head from the building’s height is utilised effectively. This is done by balancing the total pipe system losses against the effective head.

In the design of siphonic roof drainage systems, the aim is to balance the difference between the maximum and minimum calculated residual heads in every section of the system. An ideal siphonic system will have a total calculated energy loss through the piping system equal to the available design head as shown in Figure 16.13. The theoretical head shown in Figure 16.13 should not be used in the calculations as it does not account for the water level in the rainwater tank or for surcharging of the underground drainage connection pit.

In practice, it is not usually possible to balance the residual heads precisely and some imbalance will be present. It is recommended that the maximum imbalance in a siphonic system is limited to 0.5 m or 10% of the design head. The reasons that precise balancing is not possible include:

- Pipes are only available in certain sizes
- The designer does not have complete freedom in the placement of pipes and fittings
- Loss coefficients are not exact and can change with different flow conditions such as velocity and amount of air present in flow

![Figure 16.13: Design Head](image)

Figure 16.13: Design Head
Siphonic roof drainage systems require careful selection of pipe sizes unlike conventional gravity systems. Usually each tailpipe configuration will be different in siphonic systems. This is because the designer uses either different diameter pipework or different fittings to achieve the required losses to balance the system.

There are likely to be functional problems with imbalanced systems. These may include:

- The roof drainage system could have a lower capacity for rainwater disposal than specified.
- The drainage function could be irregular.
- Rainwater from roofs at high level may flow over onto lower roofs.
- The roof outlets close to the downpipe could suck air and thus 'break' the siphonic action.

Such problems can lead to considerably reduced drainage capacity, acoustic problems and dynamic loads on the installed pipework.

**Balanced Systems**

The basic aim of a balanced siphonic system is to achieve equal flowrates at all outlets. Equal flowrates are achieved by balancing the friction and form losses within the pipe system.

This can be accomplished by changing:

- pipe diameters
- outlet types
- pipe lengths
- use of expanders and reducers

Figure 16.14 illustrates how a system may be balanced by reducing pipe sizes. In this case the pipe sizes of the tailpipes have been reduced in the direction of flow towards the downpipe. This is usually referred to as “choking” the flow and this restricts the volume of flow into a specific outlet.
The design process is also discussed in general in Chapter 3. A Design Calculation Checklist is provided in Appendix A. A number of the steps in the design process are discussed below.

Design Objectives

The design objective will vary from site to site but in most cases the key objectives will be to prevent flooding of the building and surrounding surface areas and to harvest, store and reuse rainwater. A well designed siphonic system will achieve the flood control objectives. To harvest and reuse roofwater a storage system needs to be integrated into the design. This is much easier with siphonic systems as there are much fewer downpipes and discharge points than in corresponding conventional gravity systems. However, storage can still pose several challenges on sites where there is insufficient land available to site above ground rainwater tanks. In such locations, consideration should be given to either in-building tanks or below-ground rainwater tanks.

A modular in-building tank system has been developed by Syfon Systems (P/L). This system is delivered as one metre square flat panels that are bolted together on site (Figure 16.15).
Customised panels are available for pumps, overflows and flushing outlets. In this manner, the tank can be built up to fit any space available within the building. For example, Figure 16.16 shows an in-building tank fitted into the space below a mezzanine walkway.
A more expensive storage option is to use underground rainwater tanks. These are usually constructed from concrete. Plastic and metal underground tanks are also available but buoyancy considerations have to be included in the design when these types of tanks are empty. A schematic diagram and photograph of a below-ground rainwater tank are shown in Figures 16.17 and 16.18.
Check the Design Objectives

This step involves confirming the design objectives, defined as part of the conceptual design, to ensure the correct siphonic system design is selected.

Obtain Approvals (if required)

If a development application is required, key siphonic system information to be collated and provided with the application may include (if available/appropriate):

- Objectives of the siphonic system.
- Details of the size, hydrological and hydraulic response of the roof catchment.
- Details of the harvesting and reuse system (if applicable).
- Sketches/plans of the proposed siphonic system.
- Details of the performance of the siphonic system.
- Details of the connection of the siphonic roofwater harvesting system to the downstream Council operated stormwater pipe system.
- Maintenance plan for the siphonic system.
16.5 Design Tools

A range of design tools are available for the concept and detailed design of siphonic roofwater harvesting systems. The modelling tools which are able to assist include:

- Syfon Program (operated by Syfon P/L under a design and construct arrangement)
- Geberit Pluvia Software (available through distributors Reece Plumbing)
- AUS-IFD program (available from Griffith University) [www.ens.gu.edu.au/eve/Research/AusIfd/AusIfdVer2.htm](http://www.ens.gu.edu.au/eve/Research/AusIfd/AusIfdVer2.htm)
- Raintank Analyser (as described in Chapter 5 of this Manual)

A number of the modelling tools available are discussed briefly below.

**Syfon**

The Syfon program was developed by Professor Simon Beecham of the University of South Australia. Syfon is a windows-based program designed to conduct both steady and unsteady flow analysis of siphonic drainage systems.

By the programming convention used in the Syfon software, the pipe system consists of a number of reaches. A reach is defined as a consecutive sequence of pipes that runs from each inlet to the discharge point. Many pipes in the network are part of more than one reach and the most downstream pipe is part of every reach.

The data on range of pipe sizes is held in a file called pipediam.dat. This file stores the internal and external diameters of all pipes available for use on the project.

The Syfon program analyses pipe systems under full bore flow conditions, finding the flow rate, pressure and losses at any point in the pipe system. It is designed exclusively for drainage applications with a branched structure (i.e. multiple inlets to the system converging to a single discharge point).

The pipe system is geometrically located in space using nodes which are defined using Cartesian coordinates. Every pipe spans between 2 nodes, an upstream and a downstream one. The node at the upstream end of each pipe is given the same identification number as the pipe.

The discharge point (the most downstream node) is always named 0 and has the cartesian coordinates 0,0,0. All other coordinates in the network are geometrically relative to this point.

The user enters the pipe system data and the Syfon program conducts an optimization analysis. The user may also change the system, by adjusting the pipe sizes and/or the geometry of the pipe network. The system is then re-analysed and readjusted until the desired result is achieved.
The system requirements for the program are:

- An IBM compatible PC with a Pentium® 90MHz or higher microprocessor.
- Microsoft Windows NT 3.51 or later, or Microsoft Windows 95 or later.
- VGA 640x480 or higher-resolution screen supported by Microsoft Windows.
- Microsoft Excel for the bill of quantities

The program is customised software developed for Syfon Systems P/L. While the software is not distributed to clients, it is used on their behalf by Syfon Systems on a design and construct basis.

**Geberit Pluvia**

The Geberit Pluvia software is distributed through Reece Plumbing P/L. The software provides a comprehensive package of utilities. The program is able to produce isometric drawings, hydraulic calculations, material lists and cost calculations. Further details of the Geberit software are available from:


**AUS-IFD**

The AUSIFD program features include:

- Fully interactive using the Microsoft Windows Graphical User Interface.
- Fully interactive on-line help.
- Calculate design rainfall intensity based on the procedures described in Chapter 2 of Australian Rainfall & Runoff, 1987.
- Calculate design temporal patterns based on the procedures described in Chapter 3 of Australian Rainfall & Runoff, 1987.
- Calculate fully advanced storm patterns that preserve the rainfall intensity versus duration characteristics that are included in the IFD data for the site.
- Access a data file of locations within Australia at which the required design parameters have been estimated from Volume 2 of Australian Rainfall & Runoff, 1987.
- Up-date data file with new locations from within the program.
- View a map of the locations saved in the data file.
- Print a graph or table of the design rainfall IFD.
- Save temporal patterns and rainfall IFD values to an ASCII based text file
The system requirements for the program are:

- An IBM compatible PC with a Pentium® 90MHz or higher microprocessor.
- Microsoft Windows NT 3.51 or later, or Microsoft Windows 95 or later.
- VGA 640x480 or higher-resolution screen supported by Microsoft Windows.
- Microsoft Internet Explorer
- The program is free to use and distribute. Limited support is provided with the program. The AUS-IFD program may be downloaded from: [www.ens.gu.edu.au/eve/Research/AusIfd/AusIfdVer2.htm](http://www.ens.gu.edu.au/eve/Research/AusIfd/AusIfdVer2.htm)

**Raintank Analyser**

This software is designed for sizing rainwater tanks and is described in detail in Chapter 8. The program is freely available and can be downloaded from: [www.unisa.edu.au/water/UWRG/publication/raintankanalyser.asp](http://www.unisa.edu.au/water/UWRG/publication/raintankanalyser.asp)
16.6 Construction Process

Section 10 of AS/NZS 3500.3.2 details the requirements for testing that should be followed for roof drainage elements. The siphonic system should be installed only by fully trained and qualified personnel employed directly by the siphonic roof drainage contractor. All installers should be registered plumbers. The completed siphonic system should be connected to a rainwater tank with sufficient overflow relief. This should be installed by the civil contractor with an appropriate seal to the HDPE pipe.

The two types of tests specified in AS/NZS 3500.3.2 are water and air tests. Water tests involve the filling of the pipe system with water and maintaining that level for a minimum period of 5 minutes without leaks. During the testing period, visual inspections should be carried out on the pipe and joint system. The maximum head of water on a pipe section during a water test is specified as 3 metres. On the majority of roof drainage systems this distance would be a limiting factor and, in practice, may lead to more problems than it attempts to solve. This system would require a test gate be installed for testing purposes at 3 metre vertical intervals. This requirement would not only add additional cost to the building construction, it would also create a possible leakage / failure point into the system. Given the materials and jointing methods used and the operational performance of the siphonic system (which is designed to run full and under pressure), it is reasonable that the maximum head of water used in a water test could easily exceed 3 metres. For these reasons, the system should be filled from the gutter outlet down to the discharge point at the in-ground drainage system.

An alternative to this test is a simulated running water test. Water is discharged down the gutter outlet to simulate actual flow conditions and a visual inspection of the pipe system is carried out.

Air tests are similar to the water test; however the pipes should be filled with air to a pressure of no less than 30kPa for a period of no less than 3 minutes. After the pressure source is disconnected, the period of the pressure drop from 25 kPa to 20 kPa is monitored. Acceptable minimum time values for this are given in AS/NZS 3500.3.2 and depend on the pipe diameter.
16.7 Inspection and Maintenance Requirements

Siphonic systems should be maintained in the same way that conventional gravity roof and gutter systems are maintained. Removal of leaf, sediment and other debris from roof and gutter systems is essential to maintain optimal performance of the system. In addition maintaining the tank, catchment and distribution system will provide for better quality of the harvested rainwater. It is important to establish a general maintenance program to ensure the siphonic system continues to provide satisfactory performance.

Simple, pre-scheduled clearing of debris and cleaning will maintain the system in good condition. An example Inspection and Maintenance checklist for siphonic systems is provided in Appendix B.

For rainwater tanks the following items should be inspected:

- Clogging and blockage of the tank inlet leaf/litter screen; and
- Depth of sediment within the tank.

Inspections should be undertaken at the frequencies shown in the Maintenance and Inspection Checklist for Rainwater Tanks presented in Chapter 8.

The following maintenance activities should be undertaken:

- Leaves and debris to be removed from the inlet leaf/litter screen;
- Removing leaves and debris from roof gutters; and
- Sediment and debris to be removed from rainwater tank floor.
16.8 Approximate Costs and Manufacturer Information

Costs Considerations

The costs of installing any roof drainage system in large residential, commercial and industrial buildings are very location specific and consequently it is not possible to give typical costs in this section. However, all buildings have to have roof drainage systems and the choice of whether these are conventional gravity systems or siphonic systems often comes down to overall cost. If siphonic systems were far more expensive than conventional systems it would not be the case that over 90% of new commercial and industrial buildings in the UK have siphonic systems installed.

Any roofwater harvesting and reuse scheme can be considered to be an investment and not a cost. As discussed in Chapter 8, when the costs of a rainwater tank and its accessories and connections are included, the cost per unit of water is initially higher than mains water. In the long term the proportionate cost goes down until you are saving money and helping the environment.

When comparing the cost of a siphonic roofwater harvesting scheme with a conventional gravity roof drainage system there are many factors to consider. One of the most important is the difficulty in harvesting from more than two or three downpipes in a conventional system. This means that in order to harvest all the water from a building roof, rainwater tanks often have to be placed in several locations around the building. This is generally unnecessary for a siphonic harvesting system as the pipes are brought together immediately below the roof level and tanks are only required where the combined flow is brought to ground level.

Another important difference is that downpipes in conventional systems are only designed to operate at one third full or less, while in siphonic systems pipes run full. This increased efficiency often means much smaller pipes may be used, with much less reliance on pipe slope. The cost savings associated with this are not only associated with smaller pipe sizes. A more important financial consideration arises from the overall pipe network system being more readily incorporated into the architectural and structural requirements of the building. Cost savings are therefore achieved, largely through the reduction in drainage infrastructure below the building floors.

While there are many considerations when selecting the pipe material, the main criterion is generally cost. In the majority of cases where siphonic roof drainage is applicable for use, such as in large residential, industrial or commercial buildings, the aesthetic appearance of the pipe material is not of great importance. Generally, the pipe runs are installed at high level and are out of sight or are concealed from view in ceiling voids. In these conditions, cost is the factor that determines the selection and predominantly HDPE is the preferred material.
Other considerations to take into account are the installation, maintenance and lifecycle costs. For example, typically siphonic drainage systems are installed in relatively inaccessible places and often require hoists or scaffolding for the installation. In these instances, due to the high cost of labour the selection of a pipe system that is easy to handle and quick to install may be superior to a cheaper material that will take longer to install.

Typical costs for rainwater tank systems are presented in Chapter 8.

**Manufacturer Information**

Some of the principal siphonic manufacturers are listed below:


However, it should be noted that this is not a complete (or recommended) listing.

For options regarding rainwater tanks visit [www.yellowpages.com.au](http://www.yellowpages.com.au). Useful searches include:

- Tanks and tank equipment;
- Tank cleaning; and
- Plumbers.
16.9 Case Study

Sydney Olympic Stadium

This stadium’s most iconic design feature is the translucent, saddle-shaped roof with an area of 27,500m² and spanning approximately 300m. The roof has been developed to suit Australian conditions by allowing maximum natural light during daytime events for player and spectator visibility.

The polycarbonate roof slopes down, thereby enhancing the atmosphere and optimising the venue’s acoustics, while at the same time providing effective sun and rain protection for spectators.

Olympic Stadium is one of the few stadia in the world which effectively shades and protects most spectators without creating the claustrophobic feel of a fully enclosed dome.

All rainwater is collected from the stadium roof and stored in four large tanks for irrigation of the pitch. Recycled water is utilised for the flushing of toilets and water saving devices are provided throughout the stadium. All building materials used in the stadium design have been subjected to life cycle cost assessments.

The roof structure consists of a number of channels feeding a sump basin before being drained by a combination of eight individual siphonic systems. The stadium roof drainage system consists of eaves gutter with siphonic gutter outlets.

A conventional system was originally proposed but this was later dismissed as gutter and pipe sizes would need to be too large and heavy to cater for the design rainfall. It was also impractical to locate downpipes at the front of the roof structure where spectators’ vision was impaired.

Sydney Olympic Stadium’s saddle shaped roof drains rainwater towards the front of the roof while at the same time flowing away from the centre. Smaller channels within the roof sheeting help to assist in the distribution of rainwater flow into the main collector channels. This results in greater volumes of rainwater towards the wings and creates an uneven distribution of flow along the gutter.
The consequences of the uneven flow distribution are that larger or less restricted pipes are required closer to the wings to cater for the increased flows. This is contrary to general convention for balancing level gutters. To cater for this, tailpipes closer to the downpipes have increased diameters.

The majority of the above ground pipework is manufactured from High Density Polyethylene (HDPE). At the interface between the downpipe and collector the pipe material changes to stainless steel. This material was selected because the downpipes travel underground through contaminated soil. Stainless steel pipes are used to reduce corrosion and the likelihood of material failure.

As the downpipe changes from vertical to horizontal, a number of bends are required. Radial bends have been adopted to minimise the amount of friction within the pipework. The downpipe is securely fastened to the structure supports to stop vibration and movement.
16.10 Useful Resources and Further Information

**General**

www.syfon.com/pdfs/3d_drawing.pdf  
Schematic 3D drawing showing rainwater harvesting from siphonic roofwater systems

Software to select optimal rainwater tank size (free download)

www.syfon.com/pdfs/fibreglass_tank.pdf  
In-building modular fiberglass rainwater tanks

www.ahsca.com.au  
Association of Hydraulic Service Consultants Australia

www.stormwater.asn.au  
Stormwater Industry Association

Research news item on siphonic roofwater harvesting systems

**Regulations and Legislation**

Environment Protection (Industrial Noise) Policy 1994

EPA Information Sheet on Construction Noise

EPA Information Sheet on Environmental Noise

EPA Handbook for Pollution Avoidance on Building Sites

(Websites current at August 2010)
16.11 References

American Society of Plumbing Engineers (2006), Siphonic Roof Drainage Design Standard, (Draft V3), design Standards Committee, USA.


Association of German Engineers VDI 3806, Dachentwaesserung mit Druckstroemung, Verein Deutscher Ingenieure, 2000.


Jenkins, Dr G A, AUS-IFD Version 2.0
www.ens.gu.edu.au/eve/Research/AusIfd/AusIfdVer2.htm


Weston, R., reported in Liability and Risk, Civil Engineers Australia, pp. 57-58, Institution of Engineers Australia, June 1999.


(Websites current at August 2010)
Appendix A
Checklists
# Siphonic Roofwater Harvesting System

## Design Calculation Checklist

<table>
<thead>
<tr>
<th>Asset ID:</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Building Location:</td>
<td></td>
</tr>
<tr>
<td>Building Height</td>
<td>Is the roof located higher than 4.5m above ground level?</td>
</tr>
<tr>
<td>Hydraulics:</td>
<td>Design flowrate (m³/s):</td>
</tr>
<tr>
<td></td>
<td>Overflow system design flow (m³/s):</td>
</tr>
<tr>
<td>Area:</td>
<td>Roof catchment area (ha):</td>
</tr>
</tbody>
</table>

### Siphonic Component

<table>
<thead>
<tr>
<th>Siphonic Component</th>
<th>Y/N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calculation of appropriate design flow for roof runoff</td>
<td></td>
</tr>
<tr>
<td>Calculation of number of siphonic outlets needed</td>
<td></td>
</tr>
<tr>
<td>Calculation of optimum outlet spacing and pipe lengths</td>
<td></td>
</tr>
<tr>
<td>Appropriate collector pipe and tailpipe configurations</td>
<td></td>
</tr>
<tr>
<td>Hydraulic balancing of pipes and tailpipes to available design head</td>
<td></td>
</tr>
<tr>
<td>Maintenance access provided?</td>
<td></td>
</tr>
<tr>
<td>Overall flow conveyance sufficient for design flood event?</td>
<td></td>
</tr>
<tr>
<td>Acceptable connection to downstream drainage system?</td>
<td></td>
</tr>
<tr>
<td>Adequate overflow system for storms exceeding the design event?</td>
<td></td>
</tr>
<tr>
<td>Appropriate choice of rainwater tank (check volume requirements/pump selection/overflow configuration/sump flushing)</td>
<td></td>
</tr>
</tbody>
</table>

### Comments
# Siphonic Roofwater Harvesting System

## Construction Inspection Checklist

<table>
<thead>
<tr>
<th>Asset ID:</th>
<th>Date of Visit:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Contact during site visit:</th>
<th>Time of Visit:</th>
</tr>
</thead>
<tbody>
<tr>
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<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Location:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Description:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Inspected by:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Constructed by:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
</tbody>
</table>

## Items Inspected

<table>
<thead>
<tr>
<th>Checked Y/N</th>
<th>Satisfactory Y/N</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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</tr>
</tbody>
</table>

1. Check system leakage with water test or air test, according to AS/NZS 3500.3.2

2. Check system compliant with fire safety regulations – is additional fireproofing required – e.g. intumescent sleeves

3. Confirm structural element sizes

4. Maintenance access provided

5. Check all fittings against bill of quantities (particularly reducers)

## Comments on Inspection

<p>| |</p>
<table>
<thead>
<tr>
<th></th>
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<tbody>
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</tbody>
</table>

## Actions Required

1. 

2. 

3. 

## Inspection Officer Signature:

<p>| |</p>
<table>
<thead>
<tr>
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</thead>
<tbody>
<tr>
<td></td>
</tr>
</tbody>
</table>
Siphonic Roofwater Harvesting System

Maintenance Inspection Checklist for Gutters and Outlets

| Asset ID: | Date of Visit: |
| Location: | Date of Visit: |
| Description: | Date of Visit: |
| Site Visit by: | Date of Visit: |
| Purpose of Site Visit: | Date of Visit: |
| Routine Inspection: | Date of Visit: |
| Routine Clean Out: | Date of Visit: |
| Annual Inspection: | Date of Visit: |

**Inspection of Gutters and Outlets**

<table>
<thead>
<tr>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>Check all gutters / outlets are free from obstructions and moss / sediment and/or other extraneous matter.</td>
</tr>
<tr>
<td>Remove all debris from gutter. <strong>NOTE:</strong> No debris to be flushed/discharged down the outlet.</td>
</tr>
<tr>
<td>Check for cracks, splits and corrosion.</td>
</tr>
<tr>
<td>Report any defects to the gutter supplier.</td>
</tr>
<tr>
<td>Check gutter joints for leakage.</td>
</tr>
<tr>
<td>Refer to gutter supplier for approved sealing method.</td>
</tr>
<tr>
<td>Check all leafguards / gratings for blockages.</td>
</tr>
<tr>
<td>Remove all debris, wipe leafguard / grate clean. Replace if damaged.</td>
</tr>
<tr>
<td>Check leafguards / grates are in position.</td>
</tr>
<tr>
<td>Reposition leafguard / grate. Replace if damaged.</td>
</tr>
<tr>
<td>Check gaskets and seals on outlet.</td>
</tr>
<tr>
<td>Note any deterioration in the gaskets, seals etc.</td>
</tr>
</tbody>
</table>

**Cleanout of Debris**

<p>| 1. Volume of debris removed from gutters (litres) |
| 2. Any visible damage to the siphonic system? (if yes complete section on condition) (Y/N) |</p>
<table>
<thead>
<tr>
<th>Component Condition</th>
<th>Checked? Y/N</th>
<th>Condition OK? Y/N</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gutters</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Outlets</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Seals</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Comments:**


# Maintenance Inspection Checklist for Pipework and Suspension System

<table>
<thead>
<tr>
<th>Asset ID:</th>
<th>Date of Visit:</th>
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</thead>
<tbody>
<tr>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Location:</th>
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</thead>
<tbody>
<tr>
<td></td>
<td></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Description:</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Site Visit by:</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Purpose of Site Visit:</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Routine Inspection:</td>
<td></td>
</tr>
<tr>
<td>Routine Clean Out:</td>
<td></td>
</tr>
<tr>
<td>Annual Inspection:</td>
<td></td>
</tr>
</tbody>
</table>

## Inspection of Pipework and Suspension System

<table>
<thead>
<tr>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>All pipes should be periodically inspected visually for damage or leakage, paying particular attention to pipe joints. If leakage is suspected take any necessary, temporary action as to stop leak. Contact – Siphonic System Installer / Supplier.</td>
</tr>
<tr>
<td>Pipe alignment and evidence of movement. Inspect pipe joints and bracketing system for evidence of wear and damage.</td>
</tr>
<tr>
<td>Internal brackets to be checked for soundness and degradation <strong>CAUTION:</strong> If brackets are found to be loose, check that on tightening the pipe is not distorted.</td>
</tr>
</tbody>
</table>

## Cleanout of Debris

<table>
<thead>
<tr>
<th>1. Volume of sediment removed from rainwater tank (litres)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>2. Any visible damage to the siphonic system pipework? (if yes complete section on condition) (Y/N)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
</tbody>
</table>

## Component Condition

<table>
<thead>
<tr>
<th>Component Condition</th>
<th>Checked?</th>
<th>Condition OK?</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pipe Joints</td>
<td>Y/N</td>
<td>Y/N</td>
<td></td>
</tr>
<tr>
<td>Pipes</td>
<td>Y/N</td>
<td>Y/N</td>
<td></td>
</tr>
<tr>
<td>Suspension System</td>
<td>Y/N</td>
<td>Y/N</td>
<td></td>
</tr>
<tr>
<td>Rainwater Tank</td>
<td>Y/N</td>
<td>Y/N</td>
<td></td>
</tr>
</tbody>
</table>
## Siphonic Roofwater Harvesting System

### Lifecycle Costs Checklist

<table>
<thead>
<tr>
<th>INSTALLATION</th>
<th>Y/N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Does the siphonic roofwater harvesting system satisfy:</td>
<td></td>
</tr>
<tr>
<td>(i) the design flow rate</td>
<td></td>
</tr>
<tr>
<td>(ii) harvesting and reuse requirements</td>
<td></td>
</tr>
<tr>
<td>(iii) other concerns (e.g. safety and aesthetics)</td>
<td></td>
</tr>
<tr>
<td>If no to any of the above then go no further</td>
<td></td>
</tr>
<tr>
<td>Siphonic roofwater harvesting system cost:</td>
<td></td>
</tr>
<tr>
<td>Installation cost:</td>
<td></td>
</tr>
<tr>
<td>Other costs (rainwater tank, etc.):</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>MAINTENANCE</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>What are the annual maintenance costs?</td>
<td></td>
</tr>
<tr>
<td>What is the cost of any special maintenance equipment (including for access/harnessing/etc.)?</td>
<td></td>
</tr>
<tr>
<td>What are the expected costs of disposal?</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>LIFE CYCLE COST</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>What is the estimated project duration (in years)</td>
<td></td>
</tr>
<tr>
<td>Life cycle costs = Installation costs + (n x Maintenance costs)</td>
<td></td>
</tr>
<tr>
<td>where n = project duration (years)</td>
<td></td>
</tr>
</tbody>
</table>