The Government of Saint Lucia

Ministry of Agriculture, Fisheries, Physical Planning,
Natural Resources and Co-operatives

and

Department of Economic Development, Transport and
Civil Aviation

Supporting Water Conservation and Use of Rainwater Harvesting (RWH) in Saint Lucia

Disaster Vulnerability Reduction Project (DVRP)

TRAINING MANUAL

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September, 2018

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ACRONYMS

CARICOM	Caribbean Community
CARPHA	Caribbean Public Health Agency
GWP-C	Global Water Partnership-Caribbean
IWCAM	Integrating Watershed and Coastal Areas Management
RWH	Rainwater Harvesting
TAG	Technical Advisory Group
TOR	Terms of Reference
WACDEP	Water Climate and Development Programme
WASCO	Water and Sewerage Company Incorporated
WHO	World Health Organization

INTRODUCTION

Rainwater harvesting has been practiced successfully for millennia in all parts of the world – and some recent interventions have had significant local impact. Yet rainwater harvesting potential remains largely unknown, unacknowledged and unappreciated. It is a technology that is considered to be foregone by some although there are still examples of the most rudimentary systems installed at homes around the country especially in water stressed areas.

A sufficient, clean drinking water supply is essential to life. Millions of people throughout the world still do not have access to this basic necessity. After decades of work by governments and organizations to bring potable water to the poorer people of the world, the situation is still dire. The reasons are many and varied but generally speaking, the poor of the world cannot afford the capital intensive and technically complex traditional water supply systems which are widely promoted by governments and agencies throughout the world.

As part of the Sustainable Development Goals (SDGs) which are a collection of 17 global goals set by the United Nations General Assembly and covers social and economic development issues including poverty, hunger, health, education, global warming, gender equality, water, sanitation, energy, urbanization, environment and social justice; a lot of emphasis is being placed on Goal 6 which is the provision of clean water and sanitation as 3 out of every 10 persons worldwide lack safely managed water services.

The capturing and storing of rainwater dates back thousands of years to when farmlands were being cultivated and there was a need to irrigate crops especially in times of droughts and water shortage. This prompted the start of the concept of rainwater harvesting which then spewed on the development and growth of municipal water systems especially in countries where there is an absence of rivers and other forms of surface water. Though popular and successful for many years it was abandoned after a while as a form of drinking water as societies became more health conscious as there was the prospectus of diseases spreading via this medium. However, whilst it is true that with increased urbanization the need for effective rainwater catchment and water conservation has waned this hasn’t been a major concern except in countries where the climate dictates it and water is in short supply and as such are once again returning to this ancient and vital part of greener living. Also, there is no doubt that climate change has got us thinking about water conservation once again.

With the occurrences of climate change and related natural hazards like hurricanes and droughts there is an urgent need to improve water use efficiency and develop more diversified water resources to cope with accompanying disasters such as water shortages that results from these hazards. Traditional water sources such as surface and ground water are always impacted by natural hazards and as such alternative sources of water must be sought out. As such we are turning our attentions to the skies for our salvation and revisiting the concept of rainwater harvesting.

Rainwater harvesting has always been a part of the Saint Lucian culture at the household level, particularly in the rural communities. This is evident island wide as many households still have rudimentary rainwater harvesting systems installed. However, over the last couple of decades with the development and expansion of water supply systems and networks within the various communities this tradition has seen a reduction in its use. Rainwater harvesting amongst households is predominantly used only to augment their municipal supply and non-potable water needs but at times are the main source of water in water stressed areas where persons rely on it to meet all uses. While we may be some way behind in our rainwater harvesting use, the rest of the world has been embracing it more and more in recent years as it has many uses as seen in Figure 1.

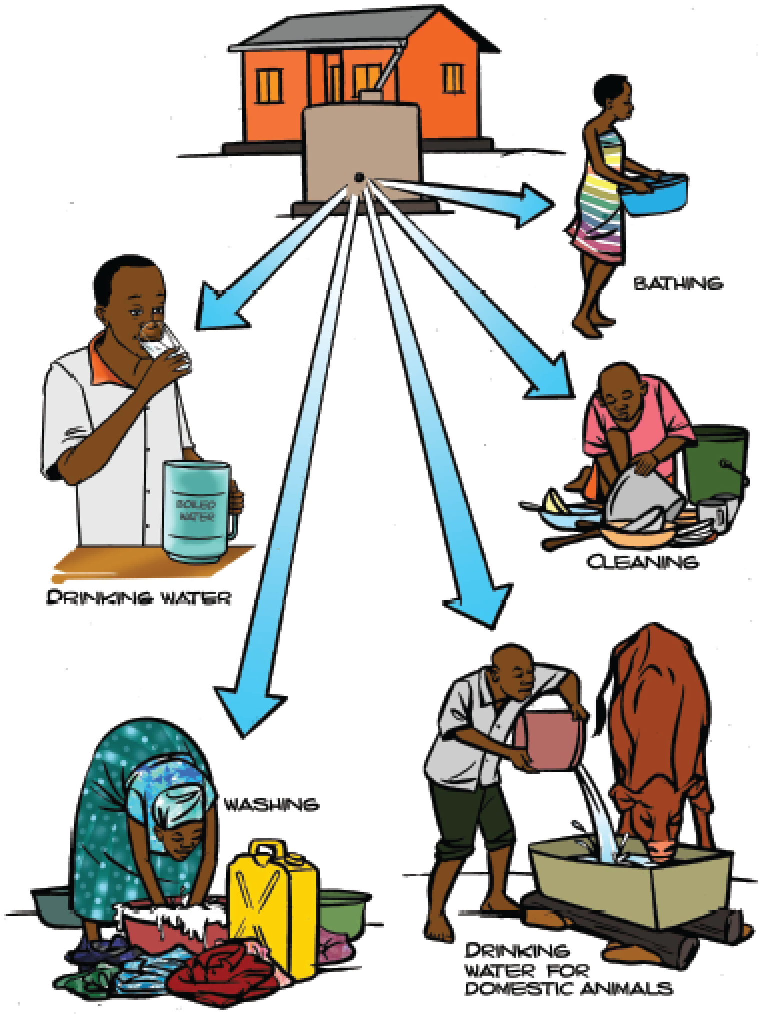


Figure 1 – Uses of rainwater

Despite the reduction in use of rainwater by households the need to save water, save money and save the environment has seen the rainwater harvesting industry develop rapidly once again in recent years. Also, given technological advancements over the years and emphasis on public health, standards and codes of practice are being developed to ensure sustainable, adequate and efficient designed rainwater harvesting systems.

Rainwater harvesting systems throughout the world is a technology that is flexible and adaptable to a very wide variety of conditions, being used in the richest and the poorest societies on our planet, and also in the wettest and the driest regions of the World.

The reason that Rainwater harvesting is rarely considered is often due to lack of information – both technical and otherwise. In many areas where rainwater harvesting has been introduced as part of a wider drinking water supply program, it was at first unpopular, simply because little was known about the technology by the beneficiaries. Despite this, rainwater harvesting is still not firmly rooted in our societies as we go deeper into the realm of climate change and the disasters associated with it. It is postulated that the reason why rainwater harvesting is rarely considered is often due to lack of information – both technical and otherwise. In many areas where rainwater harvesting has been introduced as part of a wider drinking water supply program, it was at first unpopular, simply because little was known about the technology by the beneficiaries.

Lessons have been learnt from the very first pilot rainwater harvesting systems project that was implemented in the Mabouya Valley in the Quarter of Dennery in 2007. Some of the lessons learnt has been the need for training resources and support along with ownership and buy in of the systems and also a participatory approach. In building on the lessons learnt, the Government of St. Lucia has seen it fitting to develop a Code of Practice and a Training Manual which would help guide the design and installation of sustainable rainwater harvesting systems. Therefore, the main objective of this handbook on rainwater harvesting is to provide an effective reference tool for including various rain water harvesting approaches and techniques in the programming and design of projects.

It is also designed to be a reference tool for “Train the Trainers” whereby community workers, Non-Government Organizations (NGOs), Community-Based Organizations (CBOs), Faith Based Organization (FBOs) or other people interested in rainwater harvesting can gain the requisite knowledge and pass on the knowledge and techniques. It contains a number of participatory techniques, tools and activities based on best practices from a variety of sources.

In order for households to have continued access to good quality water it is important to address both the technical and social aspects of rainwater harvesting and as such this manual is intended to be a practical reference guide on rainwater harvesting systems for technical and non-technical personnel, social and community workers involved in promoting the collection of rainwater at the household, community and institutional levels, government and non-governmental practitioners and home owners. The Handbook provides step by step procedures in the design, construction and installation of rainwater harvesting systems along with management and maintenance of the systems. To ensure the successful implementation of a rainwater harvesting system and its subsequent maintenance and repair; motivation, commitment, incentives and level of awareness are critical factors needed by participants. Therefore, in order to ensure the long-term sustainability of rainwater harvesting systems these factors need to be exhibited by the different kind of users (the household, community, public places, etc.).

DEFINITION AND AIM OF RAINWATER HARVESTING

Rainwater harvesting (WH) has been defined and classified in a number of ways by various authors over the years. The large majority of definitions are closely related, the main difference being how broad the scope is. Generally speaking, the common definition of rainwater harvesting is the collection and management of floodwater and rainwater runoff to increase water availability for domestic and agricultural use as well as ecosystem sustenance. Some persons may be surprised that rainwater harvesting includes floodwaters as we have often been made to believe that rainwater harvesting is essentially the collection of only roof water. However, to keep it simple, rainwater harvesting techniques, which harvest runoff from roofs or ground surfaces will fall under the general term “Rainwater Harvesting” while all systems which collect discharges from watercourses will be grouped under the term “Floodwater Harvesting”.

The principle of rainwater harvesting is simple as it captures potentially damaging rainfall runoff and translates it into water supply and plant growth through irrigation. This makes clear sense where rainfall is limited, uneven or unreliable with pronounced dry spells. Yet despite these rainfall limitations, runoff occurs due to high intensity showers and the low water holding capacity of soils in fields, pastures, and forests. With the impacts of climate change already upon us, now is an opportune time to take advantage and convert our threats of increased rainfall intensities of storms into opportunities by harnessing this extra water and develop an approach to better make use of a local resource for livelihood sustenance.

Therefore, the aim of rainwater harvesting is to collect runoff or surface groundwater from areas of surplus or where it is not used, store it and make it available, where and when there is a water shortage. Essentially, through rainwater harvesting there will be an increase in water availability by either (a) impeding and trapping surface runoff, and (b) maximizing water runoff storage or (c) trapping and harvesting sub-surface water (groundwater harvesting).

Rainwater harvesting makes more water available for domestic, livestock, agricultural and industry use by buffering and bridging drought spells and dry seasons through storage. Therefore, the concepts of rainwater harvesting are captured in the figure below.

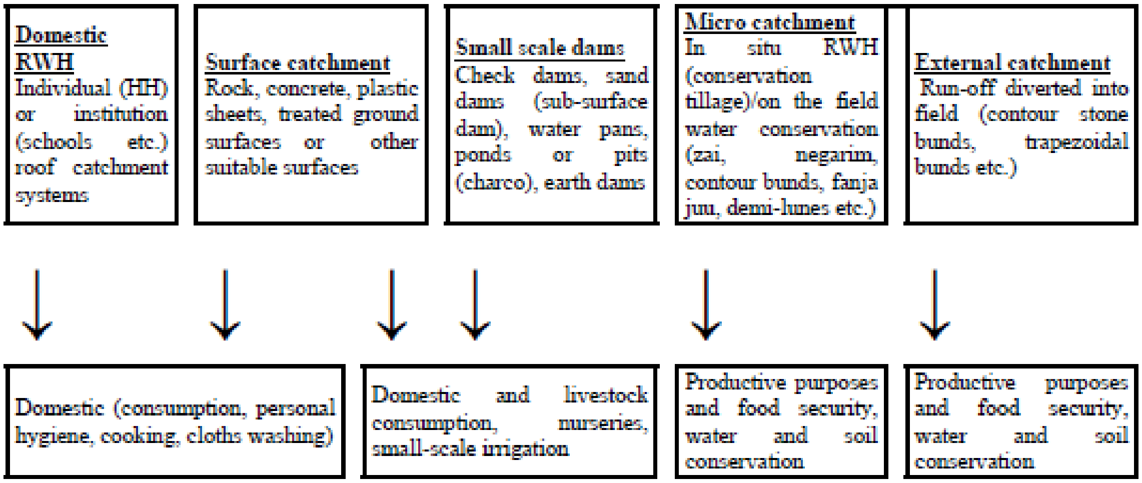


Figure 2 – Overview of Rainwater Harvesting concepts

From the concepts outlined above in Figure 2 each contributor is detailed below.

Domestic rainwater harvesting (DRWH)

- Harvesting of rainwater on roofs at individual, community or institutional level
- Consists of roof, gutters, first flush device and storage tank
- Rain pattern, catchment area and storage capacity determines the quantity
- Collected water normally has a high acceptability to users both in term of taste, odour and appearance
- The quality of water (avoidance of contaminants like faecal coliforms, turbidity and insect larvae) can be controlled by proper operation and maintenance of systems along with simple disinfections techniques
- Useful in areas with rainfall between 200 and 1000 mm per annum and especially favorable in areas with separated rainy seasons
- Areas with more or less rainfall also has potential depending upon available water resources and water quality
- Mainly used for domestic purposes

Surface catchment systems

- Harvesting of rainwater from rock outcrops/slopes, concrete surfaces, plastic sheets or treated ground surfaces
- Consist of catchment area, retention and conveyance structures and storage tank/reservoir or even low yielding wells (recharging aquifers with rainwater – categorized as recharging structures)
- Water quality acceptable to beneficiaries (taste and appearance)
- Safe water for human consumption can be assured with proper operation and maintenance and simple disinfections techniques if needed
- Useful in arid and semi-arid regions (rainfall between 200 and 750 mm per annum) – even semi-desert (< 200 mm) depending on area of surface catchment
- Used for domestic and livestock consumption mainly

Small scale dams

- Harvesting of rainwater/surface run-off within water shed and storage in various types of reservoirs
- Consist of retention structure (earth dams, stone masonry/concrete dams or simple excavated ponds), structures to extracting water (for example hand dug wells, or horizontal intake pipes connected to well shaft)
- Water quality acceptable to users and normally consumed without any further treatment
- Safe water for human consumption can be assured with proper water extraction structures and simple disinfections methods if needed
- Highly functional in arid and semi-arid region (rainfall between 200 and 750 mm) – even semi-desert (< 200 mm) depending on water availability (scarcity) and available catchment area (suitable landscape)
- Used for domestic, livestock and small-scale irrigation (e.g. kitchen gardening)

Micro catchment (inclusive of in-situ conservation)

- Overland flow/run-off harvested from short catchment length
- Catchment length between 1-30 meters
- Runoff stored in soil profile
- Ratio catchment: cultivated area (CCA) usually 1:1 to 3:1
- Since handling normally only small flows, no provision for overflow
- Plant growth is even
- Used to replenish soil moisture, increase crop production and soil conservation

External catchment systems (rainwater harvesting)

- Overland flow or runoff harvested from catchments of areas ranging from 0.1 ha to thousands of hectares
- Diverted from farmlands, hill sides, pastures, homes or even roads
- Runoff stored in soil profile or even stored in ponds, tanks or groundwater aquifers
- Catchment 30 - 200 meters in length
- Ratio catchment: cultivated area (CCA) usually 2:1 to 10:1
- Provision for overflow of excess water
- Uneven plant growth unless land levelled
- Use to replenish soil moisture, increase or ensure crop production

The success of any rainwater harvesting initiative is based upon a participatory and integrated approach. This integrated approach to water management and development discards the purely technological approach and provides a good entry point for balanced interventions in more of a programme approach rather than a project approach that have a greater chance of sustainability. Rainwater harvesting is also an integral part of sustainable land management as where it may only state land it is actually land and water management.

Sustainable Land Management (SLM) by definition is the use of land resources, including soils, water, animals and plants, for the production of goods to meet changing human needs, while simultaneously ensuring the long-term productive potential of these resources and ensuring their environmental functions.

COMPONENTS OF A RAINWATER HARVESTING SYSTEM

The basic principle of rainwater harvesting is the localized capture of precipitation falling in one area and transfer it to another area for storage, thereby increasing the amount of water available for later use. As such a rainwater harvesting system comprises components of various stages - transporting rainwater through pipes or drains, filtration, and storage in tanks for reuse or recharge. The common components of a rainwater harvesting system involved in these stages are as follows and are based on houses with general roof slopes of 1:3 found in St. Lucia.

In summary, a typical rainwater harvesting system consists basically of the supply (rainfall), the demand (water needs) and a system for collection (storage). These systems can be simple or can be complex and are made up of several components. The elements that make up a rainwater harvesting system are shown in Figures 3 and 4 below and is thus explained.

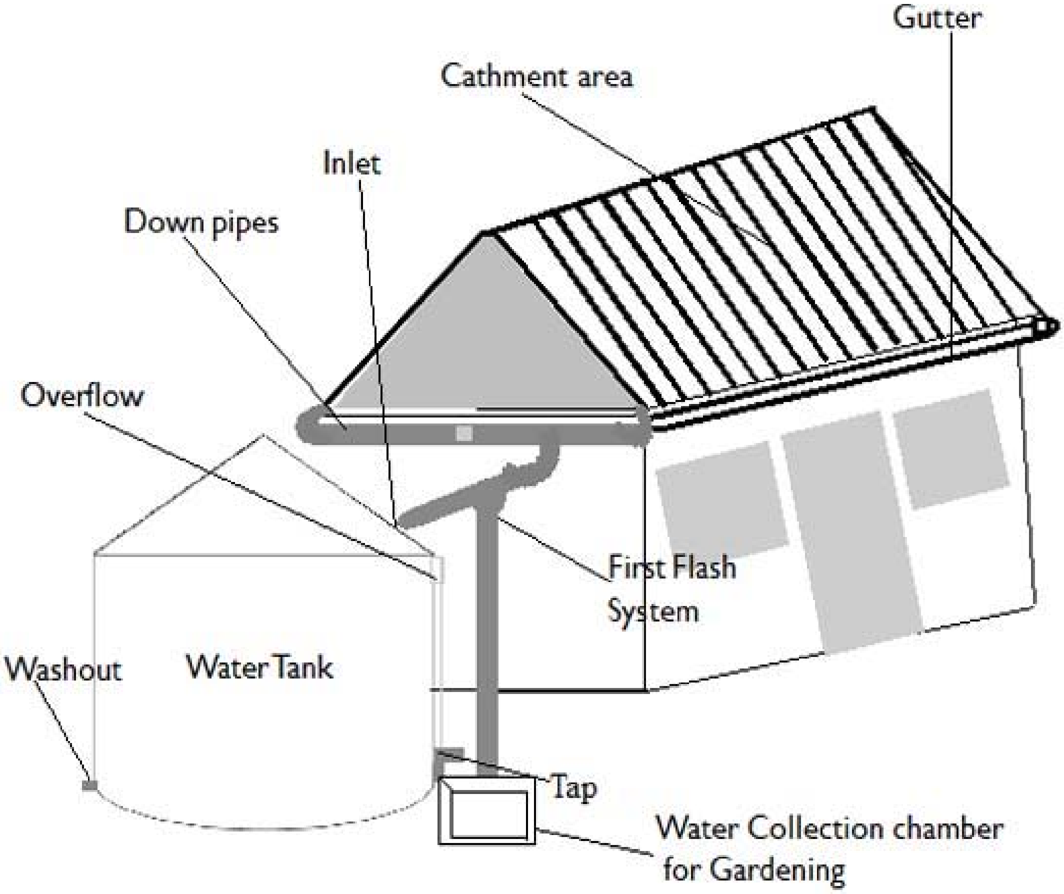


Figure 3 – Graphical representation of rainwater harvesting components

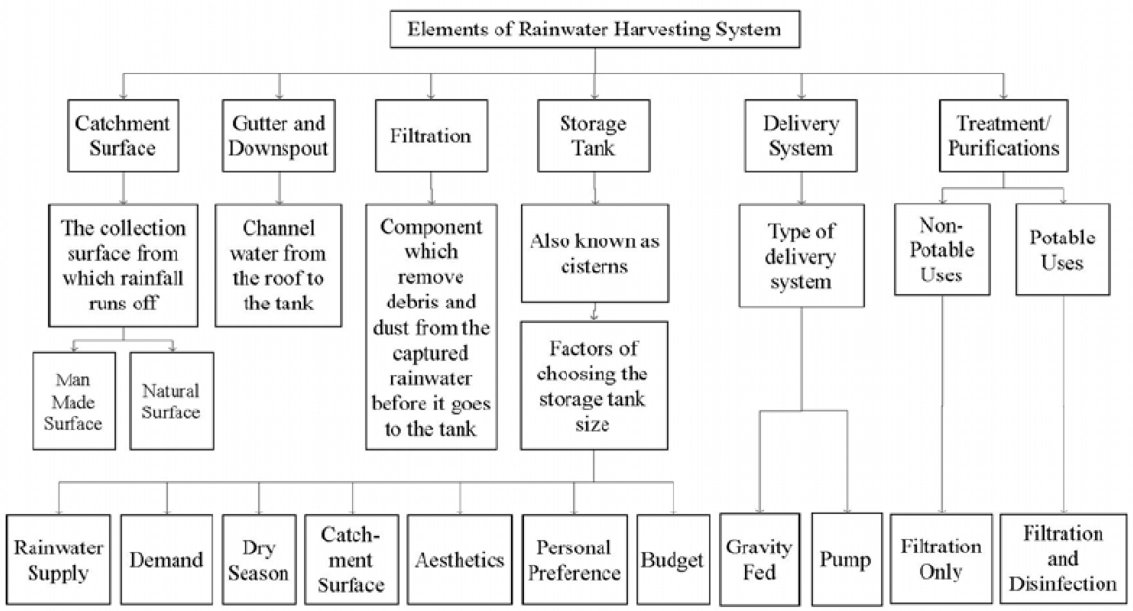


Figure 4 – Elements of a Rainwater Harvesting system

1. Catchments: The catchment of a water harvesting system is the surface which directly receives the rainfall and provides water to the system. It can be a paved area like a terrace or courtyard of a building, or an unpaved area like a lawn or open ground. A roof made of reinforced concrete (RC), galvanized iron or corrugated sheets can also be used for water harvesting.

2. Coarse Mesh (Mesh Filter): This material can be used either at the roof level or within the First Flush Diverter/Debris Trap Filter depending on the availability of space in order to prevent the passage of debris into the clean water storage vessel or storage tank.

3. Gutters: Channels all around the edge of a sloping roof to collect and transport rainwater to the storage tank. Gutters can be semi-circular or rectangular and could be made using:

- Locally available materials such as plain galvanized iron sheets (20 to 22 gauge), folded to required shapes excluding any flashing material containing lead.
- Semi-circular gutters of PVC material can be readily prepared by cutting those pipes into two equal semi-circular channels or those commercially available.
- Rectangular gutters of PVC material that is commercially available.
- Bamboo or betel trunks cut vertically in half.

The size of the gutter should be according to the flow during the highest intensity rain. It is advisable to make them 10 to 15 per cent oversize. Gutters need to be supported so they do not sag or fall off when loaded with water.

The way in which gutters are fixed depends on the construction of the house whereby it is possible to fix iron, plastic or timber brackets into the walls, but for houses having wider eaves, some method of attachment to the rafters is necessary. This will be dependent upon the method of construction used in the building of the house.

4. Conduits: Conduits are pipelines or drains that carry rainwater from the catchment or rooftop area to the harvesting system. Conduits can be of any material like polyvinyl chloride (PVC) or galvanized iron (GI) which are materials that are commonly used and are available.

5. First Flush Diverter: A first flush diverter device is a valve or conduit system that ensures that runoff from the first spell of rain is flushed out and does not enter the system. This needs to be done since the first spell of rain carries a relatively larger amount of pollutants from the air and catchment surface. Within this device, the Debris Trap Filter can be installed to prevent the passage of debris into the clean water system.

6. Filter: The filter is used to remove suspended pollutants from rainwater collected from the roof. A filter unit is a chamber filled with filtering media such as fibre, coarse sand and gravel layers to remove debris and dirt from water before it enters the storage tank or recharges structure. Charcoal can be added for additional filtration.

7. Storage facility: There are various options available for the construction of these tanks with respect to the shape, size and the material of construction. They can be either Cylindrical, rectangular or square and can be made of various types of material such as reinforced concrete, (RC), ferrocement, masonry, plastic (polyethylene) or metal (galvanized iron) sheets. Depending on space availability these tanks can be constructed above ground, partly underground or fully underground (See Appendix A). Some maintenance measures like cleaning and disinfection are required to ensure the quality of water stored in the container.

8. Recharge structures: Rainwater may be charged into the groundwater aquifers through any suitable structures like dug wells, bore wells, recharge trenches and recharge pits. Various recharge structures are possible - some which promote the percolation of water through soil strata at shallower depth (e.g., recharge trenches, permeable pavements) whereas others conduct water to greater depths from where it joins the groundwater (e.g. recharge wells).

DESIGNING A RAINWATER HARVESTING SYSTEM

An old technology is gaining popularity in a new way in this modern technologically advanced world. Rain water harvesting is enjoying a renaissance as its history traces back to biblical times. Extensive rain water harvesting apparatus existed 4000 years ago in Palestine and Greece. In ancient Rome, residences were built with individual tank/cisterns and paved courtyards to capture rain water to augment water from city's aqueducts. Today, modern rainwater harvesting techniques have not seen any significant departure from its ancient practices but rather the inclusion of technology to address health concerns.

In designing a rainwater harvesting system there are essentially four main steps which must be followed which are (1) site analysis, (2) system design and layout, (3) calculations and (4) construction and field testing. Also, materials requirements must also be considered as highlighted in Appendix B.

First and foremost, site analysis will lay the foundation by determining the suitability of the area in question and the type of system to be installed. However, a number of site-specific features will influence how the system is designed and/or utilized. The following are key considerations for rainwater harvesting feasibility and are not comprehensive or conclusive but rather, they are recommendations to consider during the planning process. They are as follows:

Available Space: Adequate space is needed to house the tank/cistern and any overflow piping. Space limitations are rarely a concern with rainwater harvesting systems if they are considered during the initial building design and site layout of a residential or commercial development. Tanks/cisterns can be placed underground, indoors, outdoors adjacent to buildings, and on rooftops that are structurally designed to support the added weight. Designers can work with architects and landscape architects to creatively site the tanks/cisterns. Underground utilities or other obstructions should always be identified prior to final determination of the tank/cistern location.

Site Topography: Site topography and tank/cistern location should be considered as they relate to all of the inlet and outlet invert elevations in the rainwater harvesting system. The final invert of the tank/cistern outlet pipe at the discharge point must match the invert level of the receiving mechanism (e.g. natural channel, storm drain systems, etc.) and must be sufficiently sloped to adequately convey this overflow. The elevation drops associated with the various components of a rainwater harvesting system and the resulting invert elevations should be considered early in the design, in order to ensure that the rainwater harvesting system is feasible for the particular site. It will also determine whether a system will be gravity fed or pressurized using electrical pumps. Site topography and tank/cistern location will also affect pumping requirements. Locating tanks/cisterns in low areas will make it easier to get water into the tank/cisterns; however, it will increase the amount of pumping needed to distribute the harvested rainwater back into the building or to irrigated areas situated on higher ground. Conversely, placing tank/cisterns at higher elevations may require larger diameter pipes with smaller slopes but will generally reduce the amount of pumping needed for distribution. It is often best to locate a tank/cistern close to the building or drainage area, to limit the amount of pipe needed but at the same time avoiding any ponding or soil saturation within 10 feet or 3 meters of the building foundations.

Soils: Cisterns should only be placed on native soils or on fill in accordance with the manufacturer's guidelines. The bearing capacity of the soil upon which the cistern will be placed must be considered, as full cisterns can be very heavy. This is particularly important for aboveground cisterns, as significant settling could cause the cistern to lean or in some cases to potentially topple. A sufficient aggregate, or concrete foundation, may be appropriate depending on the soils and cistern characteristics. Where the installation requires a foundation, the foundation must be designed to support the cistern's weight when the cistern is full consistent with the bearing capacity of the soil and good engineering practice. The pH of the soil should also be considered in relation to its interaction with the cistern material.

Water Table: Underground storage tanks/cisterns are most appropriate in areas where the tank/cistern can be buried above the water table. The tank should be located in a manner that it is not subjected to flooding. In areas where the tank is to be buried partially below the water table, special design features must be employed, such as waterproofing, sufficiently securing and anchoring the tank (to keep it from floating), and conducting buoyancy calculations when the tank is empty. The tank must be secured appropriately with fasteners or weighted down to avoid uplift buoyancy. The cistern must also be installed according to the cistern manufacturer's specifications.

Proximity of Underground Utilities: All underground utilities must be taken into consideration during the design of underground rainwater harvesting systems. The underground utilities must be marked and avoided during the installation of underground cisterns and piping associated with the system.

Contributing Drainage Area: The contributing drainage area to the cistern is the impervious area draining to the cistern. Rooftop surfaces are what typically make up the contributing drainage area, but paved areas can be used with appropriate treatment (oil/water separators and/or debris excluders). Areas of any size, including portions of roofs, can be used based on the sizing guidelines. Runoff should be routed directly from the drainage area to rainwater harvesting systems in closed roof drain systems or storm drain pipes, avoiding surface drainage, which could allow for increased contamination of the water.

Contributing Drainage Area Material: The quality of the harvested rainwater will vary according to the roof material or drainage area over which it flows. Water harvested from certain types of rooftops and contributing drainage areas, such as asphalt sealcoats, tar and gravel, painted roofs, sheet metal, or any material that may contain asbestos may leach trace metals and other toxic compounds. In general, harvesting rainwater from such surfaces should be avoided. If harvesting from a sealed or painted roof surface is desired, it is recommended that the sealant or paint be certified for such purposes by the National Sanitation Foundation (ANSI/NSF standard) or any other internationally recognized standard.

Water Use: A determination has to be made about the possible uses of the harvested rainwater whether it will be for potable uses, non-potable uses or for irrigation. This will then determine the required water quality level and will guide the outline for the design assumptions, outline water quality risks and provide water quality end use standards. It will also determine whether an additional layer of maintenance will have to be added as potable water has a much more rigid regime in frequency of testing.

Water Quality of Rainwater: It should be noted that whereas the pH of rainfall should be neutral with a pH of 7 prevailing atmospheric condition will determine the final pH which the majority of times tends to be acidic. This acidic water may result in leaching of metals and other trace elements from roof surfaces, cistern lining or water laterals, to interior connections. It will also affect the taste of the water if being used for potable purposes. As such chemicals may be added in the cistern to buffer the acidity, if desired.

Plumbing Code: The existence of any plumbing code, standard or specification will determine the allowable indoor uses and required treatment for the harvested rainwater. In may also state the requirements for connections to buildings so as to prevent any cross contamination between municipal supplies and harvested rainwater. It may also call for the clear differentiation and identification of the various installed pipes be it, municipal water supply, waste pipes, rainwater pipes, etc.

Rainfall Data: Prevailing rainfall data for a specific area will help guide the design process by giving an indication of the required catchment area so as to provide an efficient system that will aim at maximizing the collection of rainwater. However, a balance must be struck with the size of the catchment and cost as roofing structures tend to be costly to construct. The table below can be used to determine the amount of water that can be harvested from a given catchment area.

Rainfall-mm (inch)	Liters/sq.m. (Gallons / sq. ft.)	Rainfall-mm (inch)	Liters/sq.m. (Gallons / sq. ft.)
25.0 (1.0)	30 (0.6)	200.0 (8.0)	250 (5.0)
50.0 (2.0)	65 (1.3)	225.0 (9.0)	280 (5.6)
75.0 (3.0)	95 (1.9)	250.0 (10.0)	310 (6.2)
100.0 (4.0)	125 (2.5)	275.0 (11.0)	340 (6.8)
125.0 (5.0)	155 (3.1)	300.0 (12.0)	375 (7.5)
150.0 (6.0)	185 (3.7)	325.0 (13.0)	405 (8.1)
175.0 (7.0)	220 (4.4)	350.0 (14.0)	435 (8.7)

Table 1 - Table showing the approximate yield from a roof catchment

The main calculation carried out by the designer when planning a domestic RWH system will be to size the water tank correctly to give adequate storage capacity. The storage requirement will be determined by a number of interrelated factors. They include:

- local rainfall data and weather patterns
- size of roof (or other) collection area
- runoff coefficient (this varies between 0.5 and 0.9 depending on roof material and slope)
- user numbers and consumption rates

The style of rainwater harvesting system to be employed, that is, whether the system will provide total or partial supply will also play a part in determining the system components and their size. This can be based upon the consumption rates and number of persons utilizing the system or can be based upon the amount of rainfall that is available to be harvested. This approach is often deemed as the “Demand Side Approach” or the “Supply

Side Approach". However, there is a third approach that uses computer modelling but is hardly ever utilized by professionals. It is a software programme used for simulating performance of rainwater harvesting systems with covered water storage tanks and is used to predict the performance of a rainwater harvesting system based upon the mathematical model of the actual system.

The storage capacity of the rainwater harvesting system can also be determined using one of the following methods:

a) a simplified graphical approach for residential properties, where there is consistent daily demand, for which no calculations have to be carried out
b) an intermediate approach which uses simple formulae to calculate a more accurate estimation of storage capacity than the simplified approach
c) a detailed approach for non-standard systems, where there is variable demand through the year

The simplified graphical approach is not suitable however for commercial premises as the assumptions relating to demand are not applicable. The intermediate approach may be used for certain commercial and industrial premises, such as schools and offices.

For larger rainwater harvesting systems, the size of the system needs to be analyzed using a detailed approach to ensure a cost-effective solution is developed, as seasonal variations in rainfall can affect sizing requirements even where demand is relatively predictable and consistent. Once the storage capacity has been determined, storage tanks should be selected on the basis of working capacity, rather than the total capacity of the container. The size of the tank should allow for rainfall variation; however, it should be noted that construction above a certain size based on rainfall for that area provides very limited additional benefit unless stormwater attenuation is intended.

The size of the tank will also affect how often the stored water overflows. Occasional overflowing can be useful for maintenance and might have benefits for water quality.

DESIGN METHODS – STORAGE REQUIREMENTS

There are basically three design methods that are used in designing a rainwater harvesting system. They are (1) the Graphical Approach, (2) the Demand Side Approach and (3) the Supply Side Approach. With all three approaches, the final result of all the processes is the sizing of the tank for storing rainwater for future use. The storage tank is the most expensive component of the rainwater harvesting system as costs increase proportionally with tank capacity. Therefore, adequate care must be taken to design the tank. In areas that face severe water shortage, there may be a greater need to store as much rainwater as possible, irrespective of the cost. In other areas, budget or space availability may be a limiting factor resulting in a trade-off in collection efficiency.

GRAPHICAL APPROACH **-** The simplified graphical approach for estimating storage capacity calls for the following method to be adopted to sizing the rainwater harvesting system for domestic use. The roof plan area draining to the storage tank needs to be established and the average annual rainfall depth for the location of the site should be determined from the rainfall map as shown in Figure 5 (See Appendix C for additional Rainfall Intensity Maps).

Having determined these two parameters, the next bit of information required is the number of persons in the house. The required storage for an average two-person, four-person or six-person household can be read off from the graph at the point of any diagonal line it intercepts with the contributing roof area. The storage capacity should then be read from the key of Figure 6, using the appropriate diagonal line for the point of intersection.

However, where the site has a large roof plan area and/or is in a region with high annual rainfall, the storage capacity should be determined in relation to the population in the house. The storage is based on the general rule of 15 days of average rainfall, which caters for the variability of rainfall that occurs in St. Lucia (See Table 2).

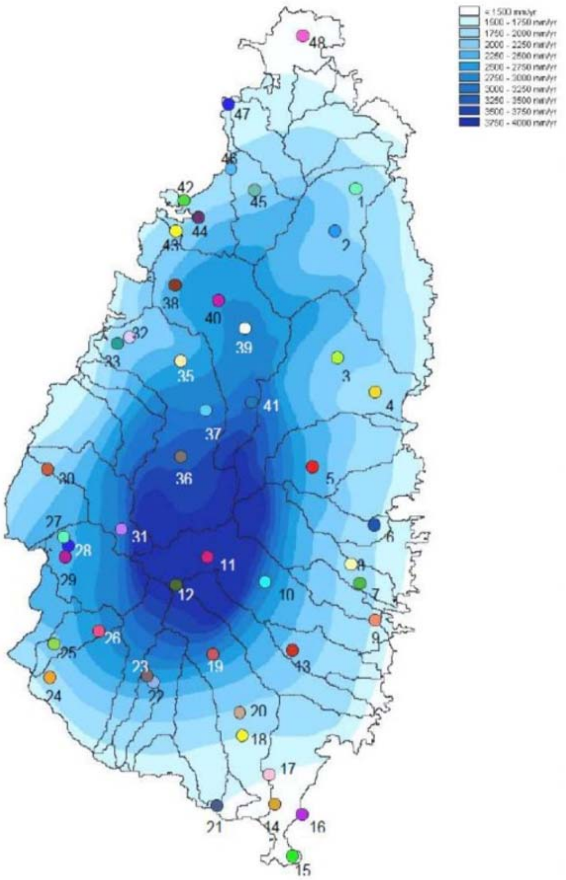


Figure 5 - Average annual rainfall map for Saint Lucia

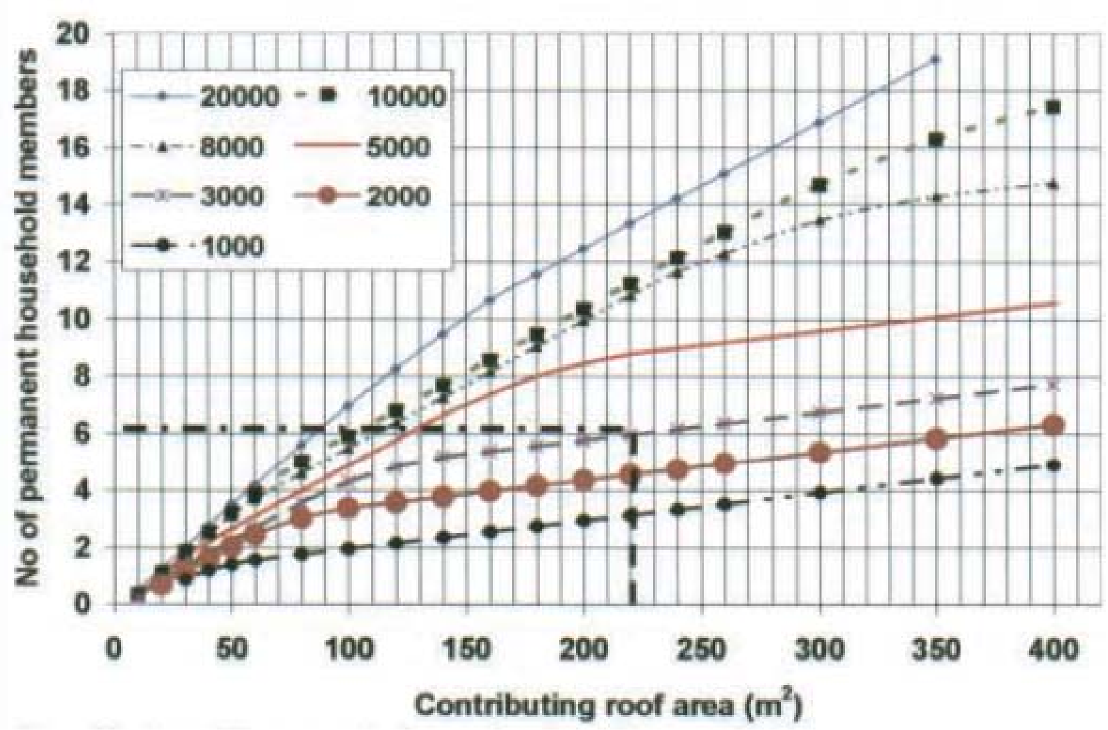


Figure 6 – Graphical guide to sizing of rainwater harvesting tanks

The simplified graphical approach however uses the following assumptions as highlighted before:

a) relatively constant daily domestic use through the year of 50 gallons or 200 liter per day per person;
b) annual average rainfall depth for the site location;
c) the use of standard tiled pitched roofs for the collection surface.

	MONTH												AVG.	TOTALS
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec		
Rainfall (mm)	125	95	75	90	125	200	245	205	225	260	215	160	168.3	2020
Rainfall (ins)	4.9	3.73	3	3.5	4.9	7.9	9.6	8.1	8.9	10.2	8.5	6.3	6.6	79.5
Rain Days	14	9	10	10	11	15	18	16	17	20	18	16	15	174

Table 2 – Typical annual rainfall data for St. Lucia

As stated previously there are a number of different methods used for sizing the tank other than the graphical approach. These methods vary in complexity and sophistication. Some are readily carried out by relatively inexperienced, first-time practitioners while others require computer software and trained engineers who understand how to use this software. The choice of method used to design system components will depend largely on the following factors:

- the size and sophistication of the system and its components

- the availability of the tools required for using a particular method (e.g. computers)
- the skill and education levels of the practitioner / designer

DEMAND SIDE APPROACH **-** Of the three approaches listed above the Demand Side Approach or the Rational Method is the simplest which can be employed by anyone and is used to calculate the largest storage requirement based upon the consumption rates and occupancy of the building or dwelling house. Essentially, the tank size is decided depending upon the following parameters, provided that the catchment area and available rainfall are adequately high, and are as follows:

- ✓ Daily water use
- ✓ Number of days for which rainwater should meet water needs (as defined by the client) or on the longest average dry period

The simple following equation is used to calculate the demand side approach

$$T = C \times D_p \times n$$

Where

T = size of the storage tank
C = Consumption per capita per day
D_p = Longest average dry period
n = Number of people per household

As a simple example we can use the following typical data:

- Consumption per capita per day, C = 200 litres or 50 gallons
- Number of people per household, n = 5
- Longest average dry period, D_p = 30 days
- Daily water consumption = C x n = 200 x 5 = 1,000 litres or 250 gallons
- Storage requirement, T = 1,000 x 30 = 30,000 litres or T=250 x 30 = 7,500 gallons

This simple method assumes that there is sufficient rainfall and available catchment area, and is therefore only applicable in areas where this is the situation. Provided that the catchment and rainfall are adequately high, a tank of capacity 30,000 litres or 7,500 gallons would ensure that the specified water demand can be met by harvested rainwater for 30 days after the tank is filled.

This calculation method is very elementary and with the maximum storage time as specified here there will be no water stored during the dry months. It is a method for acquiring rough estimates of tank sizes.

In low rainfall areas or areas where the rainfall is of uneven distribution, more care has to be taken to size the storage tank properly. During some months of the year, there may be an excess of water, while at other times there will be a deficit. If there is enough water throughout the year to meet the demand, then sufficient storage will be required to bridge the periods of scarcity. As storage is relatively expensive, this should be sized appropriately so as to avoid unnecessary expenses.

This is a common scenario in many developing countries such as St. Lucia where single wet and dry season climates prevail. In these types of climates this then calls for the Supply Side Approach.

SUPPLY SIDE APPROACH **-** This method is more commonly used by rainwater harvesting practitioners to design storage capacities. It requires long term rainfall data which can be obtained from the St. Lucia Meteorological Services offices of the Ministry of Infrastructure, Ports, Energy and Labour. Results obtained by using daily or weekly rainfall averages would be more accurate than those obtained by using monthly rainfall averages and are therefore preferred. A limitation would be the availability of daily or weekly averages of rainfall data as against monthly or annual values.

In all cases, the design of storage sizing for rainwater harvesting should consider the cost-to-benefit ratio. The most suitable size can be arrived at after considering both issues.

The system sizing calculations that are typically undertaken are elaborated in the sections below. Calculations are done using monthly rainfall data and monthly water demand patters, so that the concept can then be easily understood. The concept can also be extended further to work with weekly rainfall data.

In order to arrive at a required supply, you must first understand the demand requirement. Water demand varies widely and depends on the season, the activity for which the water is being used for and the number of people using it. It needs to be calculated on a case-by-case basis. Outlined below in Table 3 are some conservative domestic water consumption data expressed in litres per capita per day that can be used. However, these can vary but for design purposes it is recommended that 200 litres or 50 gallons per capita per day is utilized.

Activity	Quantity (litres/capita/day)
Cooking	4
Drinking	3
Bathing	18
Washing	45
Flushing	37
Gardening	28
TOTAL	**135**

Table 3 – Domestic water consumption per capita per day

As a simple example we can use the following typical data for a small household with a corrugated roof building.

Demand:

Using the Demand Side Approach equation as before to calculate the demand

$$T = C \times D_p \times n$$

where

- Consumption per capita per day, $C = 200$ litres or 50 gallons
- Number of people per household, $n = 5$
- Longest average dry period, $D_p = 30$ days
- Daily water consumption $= C \times n = 200 \times 5 = 1{,}000$ litres or 250 gallons
- Storage requirement, $T = 1{,}000 \times 30 = 30{,}000$ litres or $T=250 \times 30 = 7{,}500$ gallons

Total demand: 1,000 litres (250 gallons) per day or 30,000 litres (7,500 gallons) per mean 30-day month

Supply:

The rainwater yield or the quantity of rainwater that can be collected from a given catchment area over a period of time is

$$Q = A \times R \times C$$

Where

Q = rainwater yield = quantity of rainfall collected from the catchment area (litres)
A = catchment area (sqm)
R = average precipitation (mm)
C = run-off coefficient for a catchment material

From the above equation, based upon the type of roofing material the runoff coefficient can vary as seen in Table 4.

Type of Catchment	Coefficients
Roof Catchments	
Tiles	0.8 – 0.9
Corrugated metal sheets	0.7 – 0.9
Ground Surface Coverings	
Concrete	0.6 – 0.8
Brick pavement	0.5 – 0.6
Untreated Ground Catchments	
Soil on slopes less than 10%	0.1 – 0.3
Rocky natural catchments	0.2 – 0.5

Table 4 – Runoff coefficients for various catchment types

Therefore

- Roof area: 190 m^2 or 2,045 ft^2
- Runoff coefficient (for new corrugated GI roof): 0.9

- Average annual rainfall: 1056mm (41.6 ins. Or 3.47 ft.) per year
- Annual available water (assuming all is collected) = 190 x 1.056 x 0.9 = 180.6 m^3
  Or = 2045 x 3.47 x 0.9 = 6,387 ft^3

Daily available water = 180,576 / 365 = 494.7 litres per day or 108.8 gallons per day which translates to 14,840 litres per mean month or 3,264 gallons per mean month.

Based on the above if we want to supply water all the year to meet the needs of the household, the demand cannot exceed 494.7 litres or 108.8 gallons per day. The expected demand cannot be met by the available harvested water as demands are greater than supply. As a result, careful water management will therefore be required and will call for water rationing or prioritizing use of available water by eliminating such uses as watering of lawns and gardens and washing of vehicles, etc.

If more detail is needed then a tabular method of calculating the storage tank size is employed. The calculations are made based on available monthly rainfall data. If weekly or daily rainfall data is used, the sizing becomes more accurate. In setting up the table, the calculations must start with the month where there is rainfall after a significant dry period (See Appendix D).

An example is given below with the following parameters.

Roof Area = 200 m^2
Runoff Coefficient = 0.8
Collection Efficiency = 0.8
Number of persons per household = 4
Daily Water Demand = 800 liters

Month	Days in the Month	Rainfall (mm)	Monthly Water Yield (liters) A	Cumulative Water Yield (liters) B	Monthly Water Demand (liters) C	Cumulative Water Demand (liters) D	Volume Stored (liters) B - D	Monthly Deficit/Surplus (liters) A - C
June	30	200	27520	27520	24000	24000	3520	3520
July	31	245	33712	61232	24800	48800	12432	8912
August	31	205	28208	89440	24800	73600	15840	3408
September	30	225	30960	120400	24000	97600	22800	6960
October	31	260	35776	156176	24800	122400	33776	10976
November	30	215	29584	185760	24000	146400	**39360**	5584
December	31	160	22016	207776	24800	171200	36576	-2784
January	31	125	17200	224976	24800	196000	28976	-7600
February	28	95	13072	238048	22400	218400	19648	-9328
March	31	75	10320	248368	24800	243200	5168	-14480
April	30	90	12384	260752	24000	267200	0	-11616
May	31	125	17200	277952	24800	292000	0	-7600
TOTAL		**2020**			**292000**			**-14048**

Table 5 – Calculation of storage tank size

From the example given above the minimum storage required is 39.5 m^3 or approximately 8,700 gallons. The minimum storage required is the difference between the maximum volume stored and the surplus water left at the end of the year.

Other important considerations in determining the design of a system is the affordability to construct, operation and maintenance of the system. These often determine the size and complexity of the system.

Despite the factors as listed above there are still however 10 very important steps to follow to ensure sustainable rainwater harvesting. These 10 steps are as follows and are fully explained in Appendix E:

1. Ensure that the roof surface is suitable for collecting quality rainwater
2. Install gutters to standards
3. Install a fire proof gutter mesh system to prevent leaves and debris from blocking gutters
4. Fit gutter outlets on the underside of the roof gutter to minimize sludge build up
5. Fit rain heads to downpipes to divert leaves and debris
6. Prevent insect entry
7. Fit appropriately sized first flush water diverter/s
8. Select an appropriate water tank, tank 'top-up' and pump system
9. Draw water for usage from the aerobic zone
10. Ensure the system is maintained

FIRST FLUSH DIVERTER

The numerous steps outlined previously considered the requirements for the feasibility criteria of a rainwater harvesting system along with conveyance criteria and pre-treatment criteria. The feasibility criteria were as follows:

1. Available space
2. Site topography
3. Soils
4. Water table
5. Proximity of underground utilities
6. Contributing drainage areas
7. Contributing drainage areas materials
8. Water use
9. Water quality of rainwater
10. Plumbing code
11. Rainfall data

The conveyance criteria took into consideration the following for which the collection and conveyance system consists of the gutters, downspouts, and pipes that channel rainfall into the cisterns.:

1. Calculation of storage requirements
2. Ensure that the roof surface is suitable for collecting quality rainwater
3. Installing gutters to standards
4. Install a fire proof gutter mesh system to prevent leaves and debris from blocking gutters
5. Select an appropriate water tank, tank 'top-up' and pump system
6. Draw water for usage from the aerobic zone

The pre-treatment criteria take into consideration the following for which prefiltration is required to keep dust, sediment, leaves, contaminants, and other debris from entering the system. Leaf screens and gutter guards meet the minimal requirement for prefiltration of small systems, although direct water filtration is preferred. The purpose of prefiltration is to significantly cut down on maintenance by preventing organic buildup in the cistern, thereby decreasing microbial food sources for which the following are considered:

1. Fit gutter outlets on the underside of the roof gutter to minimise sludge build up
2. Fit rain heads to downpipes to divert leaves and debris
3. Prevent insect entry
4. Fit appropriately sized first flush water diverter/s
5. Ensure the system is maintained

The main pre-treatment option that is considered when designing a rainwater harvesting system is the first-flush diverter (See Figure 7). A first-flush diverter helps keep your rainwater harvesting system clean by enabling the removal of dust, other debris, and any fecal matter that collects on your roof and in your gutters between rainfalls, so it is flushed out at the very beginning of the water collection process (See Appendix F).

The cleaner your water is as it goes into your system, the cleaner your water will be when you use it. Studies have shown a tremendous drop in fecal bacteria levels when the roof is flushed before water enters the tank. Bacteria also like to live in decaying leaves and other organic matter that collects at the bottom of the tank. A first-flush diverter "washes" the roof, so there is less rubbish on the tank's bottom.

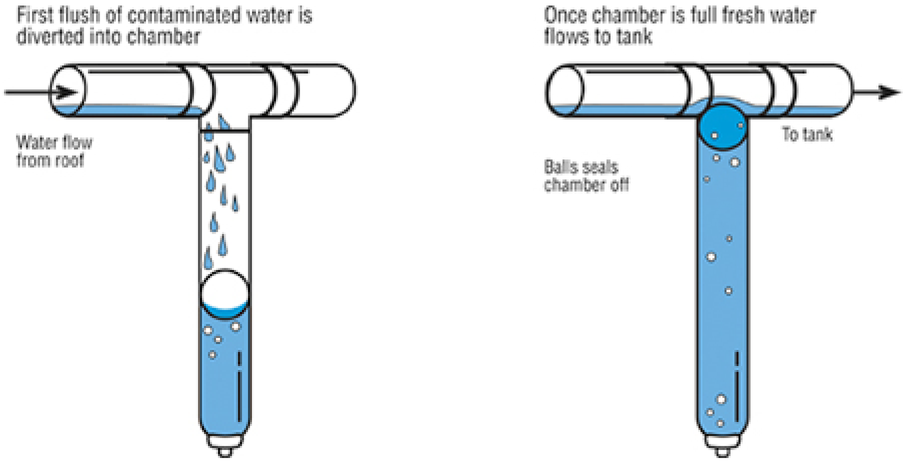


Figure 7 – First Flush Diverter Diagram

A first-flush diverter is a simple installation that is part of the downpipe system and is configured to remove the initial wash off the roof so it does not enter the tank. It works by diverting the first flow down the downpipe to its base where all debris, etc. is allowed to settle at the bottom of the downpipe, with the cleaner water settling on top, permitting relatively clean water to enter the tank. As a form of control, a floating ball acts as a shut off valve that sits on top of the water column. The floating ball isolates the dirty first flush water from the cleaner water once the water column in the downpipe floats the ball to the constriction in the neck of the downpipe.

It must be noted however that the first flush diverter needs to be emptied out following every rainfall event utilizing the hose bib at the bottom of the device. Failure to do so can lead to contamination of the system at the next rainfall event as contaminated water will not be flushed away and will flow into the tank.

It is generally assumed that a depth of rainfall on the roof equivalent to 0.50 mm is required to wash off the accumulated contaminants and debris. This is used as a guide and there is nothing preventing you from using a higher amount for safety.

In order to determine the volume of the first flush diverter you must first determine the volume of water to be diverted which is essentially the rainfall depth required for cleaning the roof area. Secondly, to determine the length of first-flush down-pipe diversion requires you divide the required volume of water to be diverted, by the cross-sectional area of the pipe (πr2), where π = 3.14 and r is the radius or half the diameter of the pipe.

Vol. of diverted water (liters) = house length (m) x house width (m) x 0.5 (mm)
(multiply answer by 0.22 to convert the value to imperial gallons)

Pipe length (m) = Vol. of diverted water (l) ÷ [3.14 x r^2 (mm) x 0.001]
Pipe length (feet) = Vol. of diverted water (gal) x 22.57 ÷ [3.14 x r^2 (inch)]

A worked example:

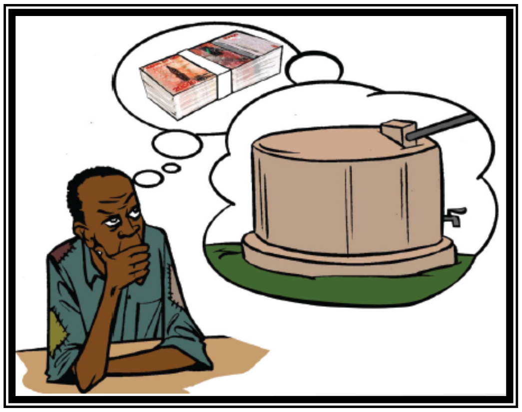
Roof length = 8 meters
Roof width = 5 meters
Pipe diameter = 150 mm (6 inches), therefore radius = 75 mm (3 inches)

Volume of diverted water (liters)= 8 x 5 x 0.5 = 20 liters (or 4.4. gallons)
Pipe length (m)=20 ÷ [3.14 x 75^2 x 0.001] = 1.13 m
Pipe length (ft) = 4.4 x 22.57 ÷ (3.14 x 32) = 3.51 ft

It is preferable to fit the longest length of first flush diverter possible to ensure better quality water and it should be installed at least 6" above the ground to allow for easy access to the end cap.

The remaining components of the systems addresses the treatment facilities that speaks to water quality both chemically and biologically.

TREATMENT AND TREATMENT OPTIONS



Treatment systems requires treatment units (filters, disinfection), pumps, and treated water storage. In any rainwater harvesting system the two most costly items are the latter, which are the pumps and tanks. Despite the initial high capital outlay, the return on investments are well worth the time, effort and financial resources expended on a rainwater harvesting system. In the designing of rainwater treatment system and treated water storage facility the following must be kept in mind:

1. The harvested water must be stored and treated before it reaches the point where it will be consumed.
2. The treatment system must be able to protect the consumer from chemical and microbiological contaminants.
3. The treated water storage tank must be able to prevent the treated water from being re-contaminated.
4. The treated water storage facility must be able to supply enough water to meet the demands.

The raindrop as it falls from the cloud is soft, and is among the cleanest water sources. Use of captured rainwater offers several advantages:

- ✓ Rainwater is sodium-free, a benefit for persons on restricted sodium diets
- ✓ Irrigation with captured rainwater promotes healthy plant growth. Also, being soft water, rainwater extends the life of appliances as it does not form scale or mineral deposits; etc.

The environment, the catchment surface, and the storage tanks affect the quality of harvested rainwater. With minimal treatment and adequate care of the system, however, rainfall can be used as potable water, as well as for irrigation. The falling raindrop acquires slight acidity as it dissolves carbon dioxide and nitrogen. Contaminants captured by the rain from the catchment surface and storage tanks are of concern for those intending to use rainwater as their potable water source.

The testing parameters which have been utilized for testing RWH systems that are designed for potable uses are based on the WHO Guidelines for potable drinking water.

Competently harvested roof water generally has negligible levels of pollution by minerals and low levels of bacterial pollution once the system is operated and maintained accordingly. In many developing countries its quality is sometimes superior to that of such alternatives as pressured piped water, shallow well water and even deep well water based upon the prevailing environmental conditions. Conversely it may not achieve the bacteriological quality of treated water entering mains from a water works, or that of delivered water in rich countries. This is due to the fact that there can be cross contamination by third parties and unclean vessels or poorly managed harvested rainwater.

Rainwater treatment units can be categorized in several ways. For example, some treatment processes are designed to improve the safety of the water, while others are designed to improve the aesthetic quality (such as color, taste and odor).

Another way of categorizing a treatment unit is by the location of the unit to where it will be consumed. Treatment units that treats all of the water as it enters the plumbing system is called "Point of Entry" or POE units, while the units that treats water at the point where it is actually to be consumed is called "Point of Use" or POU units.

Although the POE and POU approaches can both provide adequate protection if properly installed, it is however, recommended that the POE unit be used especially when treating for contaminants that pose a potential health threat. Using the POE system ensures that all the water in the building is safe for use. The developed designs for this project utilizes the Point of Entry system in that all water is treated prior to the entry into the plumbing system. All water is treated between the storage tank and the point whereby it enters the facility. As such there are basically five factors that affect harvested rainwater quality and are as follows and thus explained.

***pH (acidity/alkalinity)* -** As a raindrop falls and comes into contact with the atmosphere, it dissolves naturally occurring carbon dioxide to form a weak acid. The resultant pH is about 5.7, whereas a pH of 7.0 is neutral. Also, a concrete storage tank will impart a slight alkalinity to the water.

***Particulate matter* -** Particulate matter refers to smoke, dust, and soot suspended in the air. Fine particulates can be emitted by industrial and residential combustion, vehicle exhaust, agricultural controlled burns, and bush fires. As rainwater falls through the atmosphere, it can incorporate these contaminants.

***Chemical compounds* -** In agricultural areas, rainwater could have a higher concentration of nitrates due to fertilizer residue in the atmosphere. Pesticide residues from crop dusting in agricultural areas may also be present. Also, dust derived from calcium rich soils can add 1 mg/l to 2 mg/l of hardness to the water. Hard water has a high mineral content, usually consisting of calcium and magnesium in the form of carbonates. In industrial areas, rainwater samples can have slightly higher values of suspended solids concentration and turbidity due to the greater amount of particulate matter in the air.

***Catchment surface* -** When rainwater comes in contact with a catchment surface, it can wash bacteria, molds, algae, fecal matter, other organic matter, and/or dust into storage tanks. The longer the span of continuous number of dry days (days without rainfall), the more catchment debris is washed off the roof by a rainfall event.

***Tanks* -** The more filtering of rainwater prior to the storage tanks, the less sedimentation and introduction of organic matter will occur within the tanks. Gutter screens, first-flush diverters, roof washers, and other types of pre-tank filters, etc. Sedimentation reduces the capacity of tanks, and the breakdown of plant and animal matter may affect the color and taste of water, in addition to providing nutrients for microorganisms. Most storage tanks are equipped with manholes to allow access for cleaning. Sediment and sludge can be pumped out or siphoned out using hose with an inverted funnel at one end without draining the tank annually. Multiple linked tanks allow one tank to be taken off line for cleaning by closing the valve on the linking pipe between tanks.

PRE-TREATMENT

The cleanliness of the roof in a rainwater harvesting system most directly affects the quality of the captured water. The cleaner the roof, the less strain is placed on the treatment equipment. It is advisable that overhanging branches be cut away both to avoid tree litter and to deny access to the roof by rodents and lizards.

For potable systems, a plain galvanized roof or a metal roof with epoxy or latex paint is recommended. Composite or asphalt shingles are not advisable, as toxic components can be leached out by rainwater. To improve water quality, several treatment methods are can be used: boiling the water, using sand filter, house filter, etc.

It is the responsibility of the individual installer or homeowner to weigh the advantages and disadvantages of each method for appropriateness for the individual situation.

The water quality in tanks can also be maintained by ensuring darkness in the tank as it prevents photo-synthesis and the growth of algae. Also, by preventing the entry of suspended materials reduces the general nutrient levels supporting any biological chain or regrowth of bacteria.

Water quality is monitored by checking various parameters in the water which requires laboratory analysis to ascertain such, but for our purposes our main parameter to be regularly tested is the residual chlorine. This can be easily monitored by the regular use of pool testing kits which are readily available at hardware stores. Outlined below are some general guidelines for potable uses in Table 6.

Parameter	Guideline Values	System Type
Dissolved oxygen in stored rainwater	>10% saturation or >1 mg/l O_2 (whichever is least) for all uses	All systems
Suspended solids	Visually clear and free from floating debris for all uses	All systems
Colour	Not objectionable for all uses	All systems
Turbidity	<10 NTU for all uses (<1 NTU if UV disinfection is used)	
pH	5 – 9 for all uses	Single site and communal domestic systems
Residual chlorine	<0.5 mg/l for garden watering <2 mg/l for all other uses	All systems, where used
Residual bromine	<2 mg/l for all uses	All systems, where used

Table 6 - Guideline values for general system monitoring

The provision of drinking-water must not only be safe but also acceptable in appearance, taste and odour is of high priority. Water that is aesthetically unacceptable will undermine the confidence of consumers, will lead to complaints and, more importantly, could lead to the use of water from sources that are less safe. To a large extent, consumers have no means of judging the safety of their drinking-water themselves, but their attitude towards their drinking water supply and their drinking-water suppliers will be affected to a considerable extent by the aspects of water quality that they are able to perceive with their own senses.

It is natural for consumers to regard with suspicion water that appears dirty or discolored or that has an unpleasant taste or smell, even though these characteristics may not in themselves be of direct consequence to health. Color, cloudiness, particulate matter and visible organisms may also be noticed by consumers and may create concerns about the quality and acceptability of a drinking-water supply. As such some basic parameters are outlined below in Table 7 and the full WHO Guidelines can be found online.

Use	Minimum Water Quality Guidelines	Suggested Treatment Options
Potable Indoor Uses	• Total coliforms – 0 • Fecal coliforms – 0 • Protozoan cysts – 0 • Viruses – 0 • Turbidity < 1 NTU	• Pre-filtration – first flush diverter • Cartridge filtration – 3micron sediment filter followed by 3micron activated carbon filter • Disinfection – chlorine residual of 0.2 ppm or UV disinfection
Non-potable Indoor Uses	• Total coliforms < 500 cfu per 100 ml • Fecal coliforms < 100 cfu per 100 ml	• Pre-filtration – first flush diverter • Cartridge filtration – 5micron sediment filter • Disinfection – chlorination with household bleach or UV disinfection
Outdoor Uses	N/A	• Pre-filtration – first flush diverter

Table 7 - Minimum Water Quality Guidelines and Treatment Options for water reuse

Water quality and its impact on human health is a primary concern with rainwater harvesting. This issue is comprised of two components: end use of the rainwater and treatment provided. Despite satisfying these two requirements there can exist recontamination of systems by cross contamination.

FILTRATION

A rainwater system should deliver clean water by simply opening a faucet, just like any other water supply system. In order to be reliable and effective, each component of a rainwater system must be specifically engineered for rainwater harvesting. It is difficult to design a single treatment process that will provide complete protection against all pathogens. Although it is possible that a filtration system or a disinfection system could each achieve adequate levels of protection (99.9%) by themselves, however, it is recommended that a combination of both a filtration and disinfection system be used to provide multiple barrier protection. This ensures maximum protection to the consumers.

Filtration should be considered in the context of the entire rainwater treatment train presented in these design guidelines. A correctly designed rainwater harvesting system is not entirely reliant on just one element to protect water quality. For rainwater supply to in-house uses a sediment filtering system has to be used. A cartridge system that includes 20 - 30 micron filters is commonly chosen to remove a range of organics and sediments. A 0.2-micron filter with activated carbon or charcoal is installed also for drinking water purposes. This would remove a range of chemicals, minerals, organics and microbes.

Water quality depends on using the whole treatment process outlined in these design guidelines and local conditions. The choice of water quality solution will also be dependent on the circumstances of people within a household. There are a variety of filter technologies to remove microbial pathogens from the harvested rainwater. Some of these filters can only remove relatively large particles, such as parasites, while others can remove extremely minute particles, such as viruses as seen in Table 8 below.

Type of Filtration System	Type of Pathogens Removed
Bag Filters	Particles and some Parasites
Cartridge Filters (5.0, 25.0, and 50.0) microns	Parasites
Micro-filtration Membrane	Parasites and most bacteria
Ultra- filtration Membrane	Parasites, bacteria and some viruses
Nano- filtration Membrane	Parasites, bacteria, viruses

Table 8 - Type of Filters and the Type of impurities they can remove

Several issues have to be taken into consideration when selecting a filtration technology that will be used in the treatment system. Listed below are some of these considerations:

- The gutter screens and pre-filters will only remove large particles. They are completely ineffective against pathogenic microbes (Parasites, bacteria, viruses).
- Not all bag and cartridge filters will remove (Parasites) therefore one need to select a unit that will specifically designed to remove suspected pathogens.
- Since bag and cartridge filters do not remove bacteria and viruses, disinfection will have to be relied entirely upon to kill or inactivate these pathogens.
- Bag and cartridge filter cannot be cleaned and reused; they must be replaced as specified by the manufacturers.

The filtration systems as being designed utilizes a combination of filters based upon varying degrees of filtration. The standard basic gravity household design will encompass a single 5.0-micron filter whereas household will also have the option of a two-filter system that will encompass both a 5.0 and 20.0-micron filter. The filtration system for public facilities will have three filters mainly a 5.0 and 20.0-micron filter along with a carbon filter. Residential homes can also utilize charcoal filters as seen in Figure 8.

The installation of additional smaller filters only ensures a greater removal of smaller particles whereas the installation of a carbon filter improves on the taste and odour of the water. Depending on the system pressure it may be necessary to install pumps on the designed system in order to drive the water through the filters as the gravitational head may be insufficient.

Figure 8 – Installation of charcoal filter and fabric filter at residential home

These filter systems are typically installed in parallel after the storage and before the extraction point for use as seen above. Low-tech custom-built filter systems using layered gravel, sand and charcoal can provide good filtration capacity but their application is limited by the challenges in sourcing the filter media and the fact that off-the-shelf filter systems and water purifying devices are easily available and affordable. There is a very wide range of such solutions on the market and they vary in level of sophistication and cost. It must be noted that filters with clear housings must be placed in a light-excluding cabinet as algae will eventually grow within the housing, reducing the effectiveness of the filter and degrading the quality of the water.

Without proper maintenance, the water quality through the filters will deteriorate, due to bacterial growth and accumulation of particulate matter within the layers. In fact, the water quality with a poorly maintained filter can be worse than if there was no filter at all. In the case of the custom-built mixed media filter systems and off-the-shelf systems, the filter media need to be replaced when showing signs of heavy fouling. The rate of replacement will depend on the cleanliness of the incoming water.

Cross-contamination of the potable water system is a critical concern for any water reuse system. Cross-contamination measures for rainwater reuse systems should be similar to those for reclaimed and graywater systems. When rainwater is integrated as a significant supply source for a non-potable indoor use, a potable make-up supply line is needed for dry periods and when the collected rainwater supply is unable to meet water demands. The make-up supply to the cistern is the point of greatest risk for cross-contamination of the potable supply.

Rainwater captured from rooftops contains significant quantities of plant debris, soil, eroded roof materials, and other solids that can clog pumps, valves, and pipes. Mineral solids collect as sediment at the bottom of storage tanks, reducing tank storage capacity. Organic solids remain in suspension and decompose, depleting oxygen and generating hydrogen sulfide and other noxious by-products. Rainwater that is harvested also generally can contain a variety of pathogenic organisms. Although the water harvested from the roof collection system usually contains few of these microbial contaminants a high level of treatment is still recommended. Providing this high level of treatment ensures that the consumers are constantly protected against water- borne diseases. The threat posed by microbiological contaminants is controlled by physically removing the contaminants with a filter or by inactivating them with a disinfectant.

There are several forms of filtering and includes pre-treatment and settling which are shown below in Table 9 along with other filtering options, their locations on the system and their individual results.

METHODS	LOCATION	RESULTS
Pre-Treatment		
Screening - Leaf screens and strainers	Gutters and downspouts	Prevents leaves and other debris from entering tank
Settling		
Sedimentation	Within tank	Settles out particulate matter
Activated charcoal	Before tap	Removes chlorine*
Filtering		
Roof washer	Before tank	Eliminates suspended material
In-line / multi-cartridge	After pump	Sieves sediment
Activated charcoal remover	After sediment filter	Chlorine, improves taste
Slow sand	Separate tank	Traps particulate matter

* Should be used if chlorine has been used as a disinfectant

Table 9 – Filtration options

The World Health Organization regulations establishes the minimum treatment requirements for public water systems that uses rainwater systems and other water sources that are susceptible to microbiological contamination. There is no single mandatory requirement for individual domestic rainwater harvesting systems. It is recommended that the same treatment system that provides the same level of protection as the one that would be used for the public water system can be used for domestic purposes.

DISINFECTION

Rainwater from a properly designed rainwater pre-filtration and storage system can be used without further treatment for landscape irrigation, garden ponds, and most exterior applications. When rainwater is used within buildings, supplemental filtration is essential and disinfection is recommended. For toilet flushing and clothes washing, a sediment filter is needed which will remove suspended solids which can clog and damage valves, and an activated-carbon filter which will remove dissolved organic matter which can cause discoloration and odors. For showering, hand washing, or drinking, chlorination or use of a high-intensity ultraviolet sterilizer to kill microorganisms that could cause illness. All filtration and disinfection components should be oversized in order to maximize performance and minimize maintenance.

There are numerous disinfection technologies; some are more appropriate than others for small applications. The two most common ones are chlorine and Ultraviolet Light (UV). Although these can be used separately, however each has their unique advantage over the other. Therefore, it is recommended that a combination of Chlorine and UV are used for the following reasons.

- UV is extremely effective against parasites, but high doses are required to inactivate some viral pathogens. In addition, UV systems do not maintain a disinfectant residual in the plumbing system.
- Free chlorine is very effective against viruses but is not very effective against parasites unless there is a long contact time of over 30 minutes at a high dosage of over 1.0 mg/l. It is also easy to maintain and measure chlorine residual in the system.

Chlorine is the most commonly used disinfectant in sanitizing water for domestic use. In small and emergency water supplies house hold bleach can be used providing the water to be treated is free of turbidity and color. If the water is turbid or colored, the chlorine dosage should be double the amount of disinfectant. Adding small quantities of chlorine to the water tank is the cheapest and most effective means of disinfection. Chlorine is an effective agent against most bacteria and viruses and provides residual protection. However, some bacteria can survive chlorination by forming resistant colonies that settle on the tank wall hence the necessity to clean the tank on an annual basis.

You should disinfect your water if one or more of the following situations occur:

- A known bacterial risk has been identified through water testing;

- Individuals are getting sick (sore stomachs; diarrhea) as a result of drinking the water;
- An animal or fecal material has entered a tank;
- Inability to completely empty the tank for cleaning.

Outlined below in Table 10 is a typical dosing regime using various concentration strengths of regular household bleach for disinfection purposes that will provide the standard level of chlorine residual for potable water as established by the WHO of 5mg/l.

Disinfectant (Chlorine) %	**Amount per 4.55 Liters of Water (ml)**	**Amount per 455 Liters of Water (lt.)**
1.0	20	2.0
2.0	8	0.8
5.0	4	0.4

Table 10 - Chlorination Quantities based upon storage levels

A small amount of the disinfectant should be mixed in a small quantity (4.55 liters) of water and poured in the tank. The treated water should then be thoroughly mixed and allowed to stand for minimum 30 minutes before using. These recommended dosages will provide a chlorine residual level of between 0.5 – 1.0 mg/l of chlorine in the stored water.

This disinfection range is in keeping with the World Health Organization Water Quality Standards. Outlined below in Table 11 are some typical disinfection mixing ratios for stored water.

Volume of water in tank		**Approximate amount of bleach (with 4% active ingredient) (cups)**
Imperial Gallons	**Litres**	
200	909	½
400	1,818	1
800	3,637	2
1,000	4,546	2 ½
2,500	11,365	5 ½
5,000	22,730	11 ½
10,000	45,461	22 ½
20,000	90,922	45 ½

Table 11 – Chlorine disinfection mixing ratios for stored water

Depending on the percentage of active ingredient, the amount to be added will need to be adjusted accordingly. For example, using bleach with 8% active ingredient would halve the amount of bleach listed in the above tables for a particular water volume (based on use of 4% active ingredient) or double the amount of bleach if using bleach with 2% active ingredient listed in the above tables for a particular water volume (based on use of 4% active ingredient). If desired, the chlorine residual can be tested using a swimming pool test kit or dip strips, which may be locally available at a pool supplies or hardware store.

Besides chlorination which is the most common and cheapest form of disinfection there are several other disinfection options and are listed in Table 12 below.

METHODS	LOCATION	RESULTS
Microbiological Treatment / Disinfection		
Boiling / Distilling	Before use	Kills microorganisms
Chemical treatments	Within tank or at pump (liquid, tablet or granular) before activated charcoal filter	Kills microorganisms
Ultraviolet light	After activated charcoal filter, before tap	Kills microorganisms
Ozonation	After activated charcoal filter, before tap	Kills microorganisms
Nanofiltration	Before use; polymer membrane (pores 10-3 to 10-6 inch)	Removes molecules
Reverse osmosis	Before use; polymer membrane (pores 10-9 inch)	Removes ions (contaminants and microorganisms)

Table 12 – Disinfection options

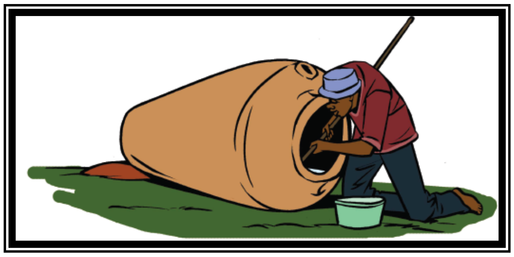
Another common form of disinfection is ultra violet sterilizers. A typical UV (ultraviolet) sterilizer consists of a UV-emitting lamp mounted within a quartz sleeve (a special type of glass tube that does not block UV) which is in turn mounted within a stainless-steel tube. Water flowing between the quartz sleeve and the stainless-steel tube is exposed to UV energy which theoretically kills any microorganisms in the water. The problem with using typical UV sterilizers for rainwater is that although rainwater is a relatively high-quality water source, it can have elevated levels of dissolved organics, iron compounds, and phosphates that absorb UV energy. Secondly, the UV lamp has a finite life span and is relatively costly to replace.

It is highly recommended that in order to provide maximum protection combinations of several processes are employed in the treatment system in the following sequence:

- Screening (course and fine)
- Storage (primarily 4,555 liters minimum)
- Filtration (3-5microns, 5-10microns, 10-25microns and 25 – 50microns)
- Disinfection (Chlorine and UV)

The combination of components as outlined above is suitable for any facility whether it be residential, commercial and institutional by the scale of intervention will be based upon the level of investment the owner is able to provide. The typical schematics for the various connections are shown in Appendix H.

MAINTENANCE OF SYSTEMS



With the independence of rainwater harvesting systems comes the inherent responsibility of operation and maintenance. For all systems, this responsibility includes purging the first flush system, regularly cleaning roof washers and tanks, maintaining pumps, and filtering water. For potable systems, responsibilities include all of the above, and the owner must replace cartridge filters and maintain disinfection equipment on schedule, arrange to have water tested, and monitor tank levels. Rainwater used for drinking should be tested, at a minimum, for pathogens. Maintenance requirements for rainwater harvesting systems vary according to use. Systems that are used to provide supplemental irrigation water have relatively low maintenance requirements, while systems designed for indoor uses have much higher maintenance requirements.

All rainwater harvesting system components should undergo regular inspections every six months. The following maintenance tasks should be performed as needed to keep rainwater harvesting systems in working condition:

- keep leaf screens, eavestroughs and downspouts free of leaves and debris;
- check screens (1 mm openings) and patch holes or gaps immediately;
- clean and maintain first flush diverters and filters, especially those on drip irrigation systems;
- inspect and clean storage tank lids, paying special attention to vents and screens on inflow and outflow spigots; and
- replace damaged system components as needed.

Rainwater used for drinking should be tested, at a minimum, for pathogens. Maintenance of a rainwater harvesting system is also an ongoing periodic duty, to include:

- ✓ Monitoring tank levels
- ✓ Cleaning gutters and first-flush devices
- ✓ Repairing leaks
- ✓ Repairing and maintaining the system, and adopting efficient water use practices

In addition, owners of potable systems must adopt a regimen of:

- ✓ Changing out filters regularly
- ✓ Maintaining disinfection equipment, such as cleaning
- ✓ Regularly testing water quality.

Maintenance responsibilities are for everyone who uses the rainwater harvesting system to cover her or his daily water demand especially when that is installed for the public usage. In the absence of any manufacturer's recommendations, the maintenance schedule given in Appendix I should be followed. The maintenance intervals listed here are for initial guidance but the frequency should be modified in the light of operational experience. A log should be kept of inspections and maintenance.

Good system design and proper operation and maintenance will reduce the possibility of contamination of the water supply. The following are summary best-practice guidelines in maintaining water quality:

- Use an appropriate roofing material and ensure that it is kept clear of dirt and soot. When this material accumulates, it promotes the growth of moss, lichen or other vegetation. Use a clean brush to sweep roofs and gutters especially before the start of the rainy season and at other times as necessary;
- Replace rusted roofing as needed. Fix any holes to realize maximum runoff. If minor rusting is present, paint using lead-free paint;
- Remove branches from overhanging trees to prevent leaf debris from falling on and accumulating on the catchment area. Branches also provide roosting for birds (with the increased opportunity for defecation), and access to the roof by rodents and other animals;
- Keep gutters clear. If the gutters sag or leak, they need to be repaired. Sagging gutter systems will retain water, providing breeding sites for mosquitoes. Leaking gutters will also cause valuable water to be wasted. Ensure guttering is slanted toward the down-pipes to ensure steady flow;
- Install a coarse filter and/or first-flush device to prevent dirt and debris entering the tank. Inspect and clean/drain these devices periodically;
- Cover all openings to tanks with mosquito mesh to prevent insects, frogs, toads, snakes, small mammals or birds entering the tank. You must inspect and clean the mesh periodically;
- Install taps or draw-off pipes above the tank floor to avoid entraining any settled material into the water flow that is to be used;
- If the tank is exposed to sunlight, make sure that it is covered or made of opaque materials or painted with opaque paint. This will exclude light and prevent the growth of algae and microorganisms;
- Clean and disinfect the tank annually. A tank floor sloping towards a sump and washout pipe can greatly aid tank cleaning;
- Tree roots can intrude underground masonry including water tanks causing them to leak. Trees in close proximity to the water tanks should be pruned or cut to restrict advancement of encroaching tree roots;
- If mosquito breeding is observed in the tank (larvae present), it is best to seek advice from your environmental health department for assistance on control measures.
- In the event when the water is contaminated by a dead animal, the tank should be drained immediately, cleaned, and disinfected with chlorine
- Monitor tanks for leaks and repair as needed;
- Hygienically store and dispense water within the household. Usually water collected from the storage tank is stored for short periods in small containers in the home.

CONCLUSION

Rainwater harvesting is the accumulation and storage of rainwater for reuse on-site, rather than allowing it to run off. Rainwater can be collected from rivers or roofs, and in many places, the water collected is redirected to a deep pit (well, shaft, or borehole), a reservoir with percolation, or collected from dew or fog with nets or other tools. Its uses include water for gardens, livestock, irrigation, domestic use with proper treatment, indoor heating for houses, etc. The harvested water can also be used as drinking water, longer-term storage, and for other purposes such as groundwater recharge. Rainwater harvesting is one of the simplest and oldest methods of self-supply of water for households usually financed by the user.

With the advances in technology, new and innovative ways are taking over and making way for rainwater harvesting systems to become much more efficient. One such way is, instead of using the roof as the catchment area, the RainSaucer, which looks like an upside-down umbrella, collects rain straight from the sky. This decreases the potential for contamination and makes potable water for developing countries a potential application. Other applications of this free-standing rainwater collection approach are sustainable gardening and small-plot farming. Also, rainwater harvesting is possible by creating freshwater-flooded forests without losing the income from the used, submerged land. Basically, you are creating a swamp with value. The main purpose of the rainwater harvesting is to use the locally available rainwater to meet water requirements throughout the year without the need of huge capital expenditure. This would facilitate the availability of uncontaminated water for domestic, industrial, and irrigation needs.

Good quality water resource, closer to populated areas, is becoming scarce and costly for the consumers. In addition to solar and wind energy, rain water is a major renewable resource of any land. Vast areas are being covered by solar PV panels every year in all parts of the world. Solar panels can also be used for harvesting most of the rain water falling on them and drinking quality water, free from bacteria and suspended matter, can be generated by simple filtration and disinfection processes as rain water is very low in salinity. Exploitation of rain water for value added products like bottled drinking water, makes solar PV power plants profitable even in high rainfall/ cloudy areas by the augmented income from value added drinking water generation.

Therefore, given the growing local interest in rainwater harvesting and also at the regional level it is an opportune time to have more persons exposed to rainwater harvesting techniques while at the same time training them in the design installation, operation and maintenance of these systems. This training manual has been written in simple terms to allow the ordinary layman to gain the basic knowledge of designing and installing a rainwater harvesting system and is also meant to be gender neutral to allow female head of households to do the same while at the same time providing additional information for more keen persons who are interested in learning more about the systems.

As mentioned previously, although rainwater harvesting had been popular and successful for many years it was abandoned after a while as a form of drinking water as societies became more health conscious and fashionable with bottled drinking water. However, with the advent of climate change and climate variability we are now being forced to change our ways of thinking and to once again embrace rainwater harvesting. There is no doubt that climate change has got us thinking about water conservation going into the next decade. With increases in intensities of cyclonic events, longer dry periods, fewer rain days, high intensity rainfall events, rising sea levels and the resultant salt water intrusion into our water supply water ways, all as a result of climate change, means that we are to look at sustainable ways of water supply. The answer is not far as it only means "Harvesting the Heavens". This technology will never die but will only keep improving in the ways the water is harvested, stored and treated for reuse.

It is hopeful that this manual will be used as a reference tool as previously indicated and will pave the way for further adoption and implementation of rainwater harvesting systems.

BIBLIOGRAPHY

1. K. H. White, L. R. Soward, and G. Shankle , *"Harvesting Storage, and Treating Rainwater for Domestic Indoor Use",* Published and Distributed by the Taxes Commission on Environmental Quality, Austin, TX 78711-3087 (2007).

2. L. P. Barrott, B. J. Lloyd, and N. J. D. Graham, *"Comparative Evaluation of two Novel Disinfection methods for small- community Water Treatment in developing countries",* J Water SRT – Aqua Vol. 39. No. 6, pp.396- 404, (1990).

3. B. J. Lloyd, R. Eudovique, *"Evaluation of Multiple Barrier Principles in Drinking Water Treatment Systems for Surface Water Sources",* 20th Engineers Conference, Cayman Islands, (1991).

4. H. J. Hrishna, C. Brown, J. Gerston, and S. Colley*, "The Texas Manual on Rainwater Harvesting",* The Texas Water Development Board, 3rd Edition (2005)

5. Arnold Pacey and Adrian Cullis, *"Rainwater Harvesting: The Collection of Rainfall and Runoff in Rural Areas - a wider focus including the capture of runoff for agricultural use"*, Practical Action Publishing.

6. John Gould, *"Rainwater Catchment Systems - Reflections and Prospects*", Waterlines Vol.18 No. 3, January 2000.

7. *"Runoff Rainwater Harvesting",* Practical Action Technical Brief

8. Roof water harvesting discussion forum, http://www.jiscmail.ac.uk/lists/rwh.html

9. *"Components of a Rainwater Harvesting System",* http://www.rainwaterharvesting.org/Urban/Components.htm

10. *"Rainwater Harvesting and Purification System",* http://www.rwh.in

11. *"Rainwater Harvesting – Practical Answers",* http://itdg.org/docs/technical_information_service/rainwater_harvesting.pdf

12. *"Domestic Roof water Harvesting – Health Issues",* http://www.eng.warwick.ac.uk/DTU/rwh/health.html

13. *"Domestic Roof water Harvesting – Sizing a DRWH System",* http://www.eng.warwick.ac.uk/DTU/rwh/sizing.html

14. CEHI, *"A Programme for Promoting Rainwater Harvesting in the Caribbean Region"*, Collaborator: United Nations Environment Programme (UNEP), 2006.

http://cehi.org.lc/rwhindex_files/Programme%20to%20Promote%20RWH%20in%20the%20Cabbean%20Region.pdf

15. A. Hutchinson, *"Rain Water Harvesting - The Barbados Experience"*, Caribbean Water and Wastewater Association (CWWA) St. Lucia Water Week, May 2009. Stantec Caribbean

16. OAS, *"Source Book of Alternative Technologies for Freshwater Augmentation in Latin America and the Caribbean - Rainwater harvesting from rooftop catchments"*, Organization of American States Washington, D.C. 1997. http://www.oas.org/osde/publications/Unit/oea59e/ch10.htm

17. E. Peters, *"Sizing of Rainwater Cisterns for Domestic Water Supply in the Grenadines"*, 2003. http://www.uwichill.edu.bb/bnccde/svg/conference/papers/peters.html

18. H. Smith, *"Rainwater Harvesting in the US Virgin Islands"*, Caribbean Water and Wastewater Association (CWWA) Conference. October 2009. University of the Virgin Islands

19. SOPAC, *"Harvesting the Heavens - Guidelines for Rainwater Harvesting in Pacific Island Countries"*, South Pacific Applied Geoscience Commission for the United Nations Environment Programme (UNEP). Collaborators: the Tonga Community Development Trust (TCDT) and the Swedish International Development Agency (SIDA), 2004. http://www.sopac.org/data/virlib/JC/JC0178.pdf

20. SOPAC, *"Harvesting the Heavens – A Manual for Participatory Training in Rainwater Harvesting"*, South Pacific Applied Geoscience Commission for the United Nations Environment Programme (UNEP). Collaborators the Tonga Community Development Trust (TCDT) and the Swedish International Development Agency (SIDA), 2004. http://www.sopac.org/data/virlib/MR/MR0544.pdf

21. TWDB, *"The Texas Manual on Rainwater Harvesting"*, Third Edition, Texas Water Development Board, 2005. http://www.twdb.state.tx.us/publications/reports/RainwaterHarvestingManual_3rdedition.pdf

22. TWDB, *"Rainwater Harvesting System Sizing Calculator"*, Texas Water Development Board, 2009. http://www.twdb.state.tx.us/assistance/conservation/Alternative_Technologies/Rainwater_Harvesting/Rain.asp

23. UNEP, *“Rainwater Harvesting and Utilisation - An Environmentally Sound Approach for Sustainable Urban Water Management: An Introductory Guide for Decision-Makers”,* United Nations Environment Programme, 2002. http://www.unep.or.jp/Ietc/Publications/Urban/UrbanEnv-2/index.asp

24. University of Warwick, *“Introduction to domestic roof water harvesting”,* Development Technology Unit, School of Engineering, 2007. http://www2.warwick.ac.uk/fac/sci/eng/research/civil/dtu/rwh/index.html

25. University of Warwick, *“Sizing the DRWH systems”,* Development Technology Unit, School of Engineering, 2006. http://www2.warwick.ac.uk/fac/sci/eng/research/civil/dtu/rwh/index.html

26. Urban Water Cycle Solutions, *“Rainwater Harvesting - Residential Design Specification”,* Rainwater Harvesting Association of Australia, 2018.http://rainwaterharvesting.org.au/wp-content/uploads/2018/01/Rainwater-Harvesting-Guide-Approved.pdf

27. *“Rainwater Harvesting - Guidance toward a sustainable water future”,* City of Bellingham Public Works Department, 2012. https://wrrc.arizona.edu/sites/wrrc.arizona.edu/files/Bellingham_Rainwater%20harvesting%20manual.pdf

28. R.W.P. May, *“Manual for the Design of Roof Drainage Systems – A guide to the use of European Standard BS EN 1256-3:2000”,* March 2003. http://eprints.hrwallingford.co.uk/1311/1/Manual-roof-drainage-system-HRWallingford-SR620.pdf

29. *“Rainwater Harvesting – BS 8515:2009 Made Easy”,* Stormsaver Limited, 2016. https://www.stormsaver.com/content/documents/Stormsaver%20BS8515%20Guide.pdf

30. J. Leung, *“Rainwater Harvesting 101”,* GrowNYC, August 2008. https://www.grownyc.org/files/osg/RWH.how.to.pdf

31. *” Rainwater Harvesting - Conservation, Credit, Codes, and Cost Literature Review and Case Studies”,* USEPA, January 2013. https://www.epa.gov/sites/production/files/2015-11/documents/rainharvesting.pdf

32. *“Codes Harvest Rainwater”,* IAPMO Green, June 2012. http://www.iapmo.org/Official%20Articles/2012-05%20Codes%20Harvest%20Rainwater.pdf

33. *“Low Impact Development Stormwater Management Planning and Design Guide - Rainwater Harvesting”,* https://cvc.ca/wp-content/uploads/2012/02/lid-swm-guide-chapter4-4.1-rainwater-harvesting.pdf

34. C. Kloss, *“Managing Wet Weather with Green Infrastructure Municipal Handbook - Rainwater Harvesting Policies”,* USEPA, December, 2008.

35. *“BS 8515:2009 - Rainwater harvesting systems - Code of Practice”,* BSI British Standards, 2009.

36. *“BS 8515:2009 - Explained”,* Raincatcher, 2009.

37. CIMH, *“Development of IDF Curves for OECS Building Code - Saint Lucia”,* OECS, 2016.

38. CEHI, *“A Handbook on Rainwater Harvesting in the Caribbean”,* UNEP, 2009

39. WHO, *“Guidelines for Drinking Water Quality”,* Fourth Edition, 2017.

40. C. Despins, *“Ontario Guidelines for Residential Rainwater Harvesting Systems”,* Connect The Drops, Ontario, Canada, 2010.

41. C. Despins, *“Ontario Guidelines for Residential Rainwater Harvesting Systems - Handbook”,* Connect The Drops, Ontario, Canada, 2010.

42. R.M. Studer and H. Liniger, *“Water Harvesting – Guidelines to Good Practice”,* Centre for Development and Environment (CDE) and Institute of Geography, University of Bern; Rainwater Harvesting Implementation Network (RAIN), Amsterdam; MetaMeta, Wageningen; The International Fund for Agricultural Development (IFAD), Rome and Swiss Agency for Development and Cooperation, Berne (SDC), 2013.

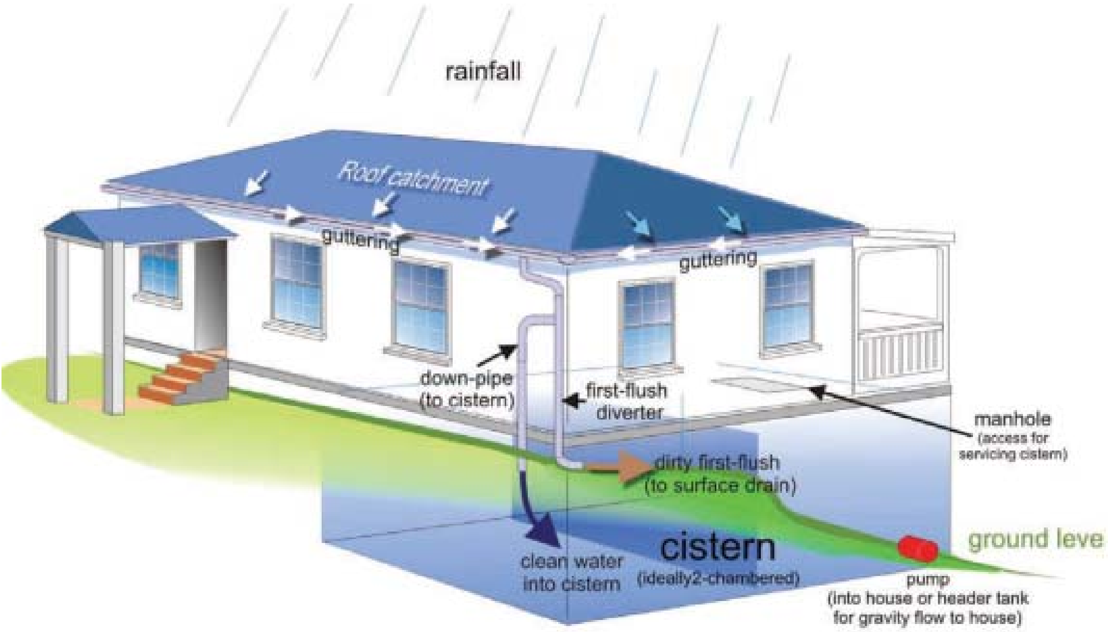
43. A.R. Shivakuma, *“Roof Top Rainwater Harvesting Trainers’ Manual”,* http://municipaladmn.gov.in/sites/municipaladmn.gov.in/files/Rainwater_Harvesting_Trainers_Manual.pdf

44. J.P. Nshimyimana, *“Guidelines for Adequate Management, Maintenance, Cleaning and Protection of Rainwater Harvesting Supply Systems”,* 2007.

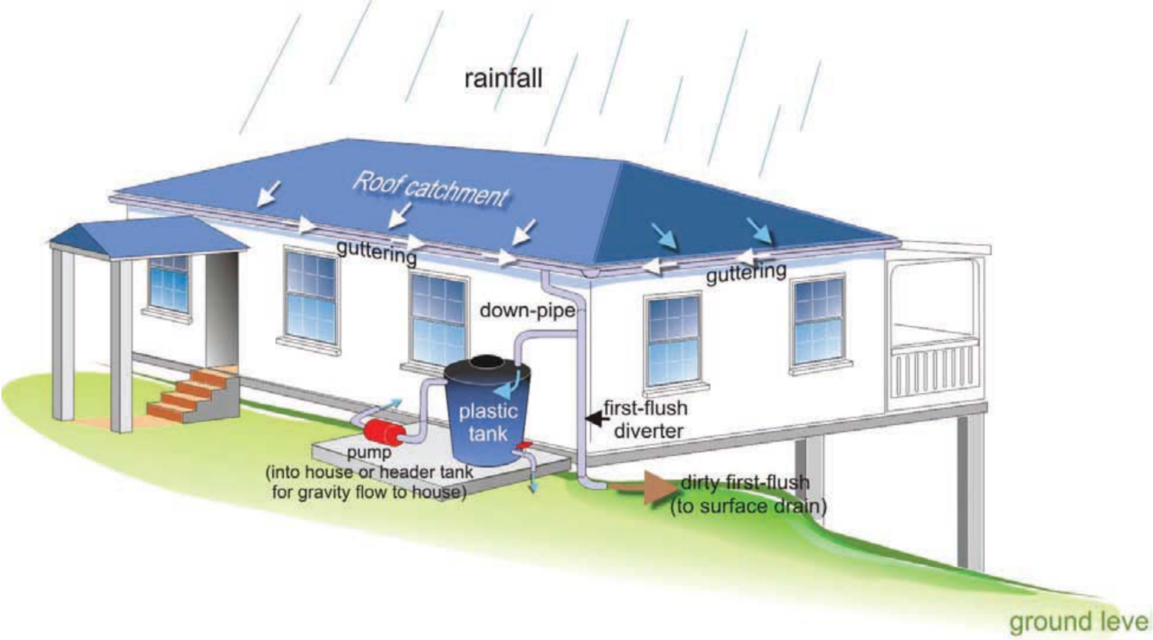
APPENDICES

APPENDIX A

Layout of Above Ground and Below Ground Rainwater Harvesting Systems

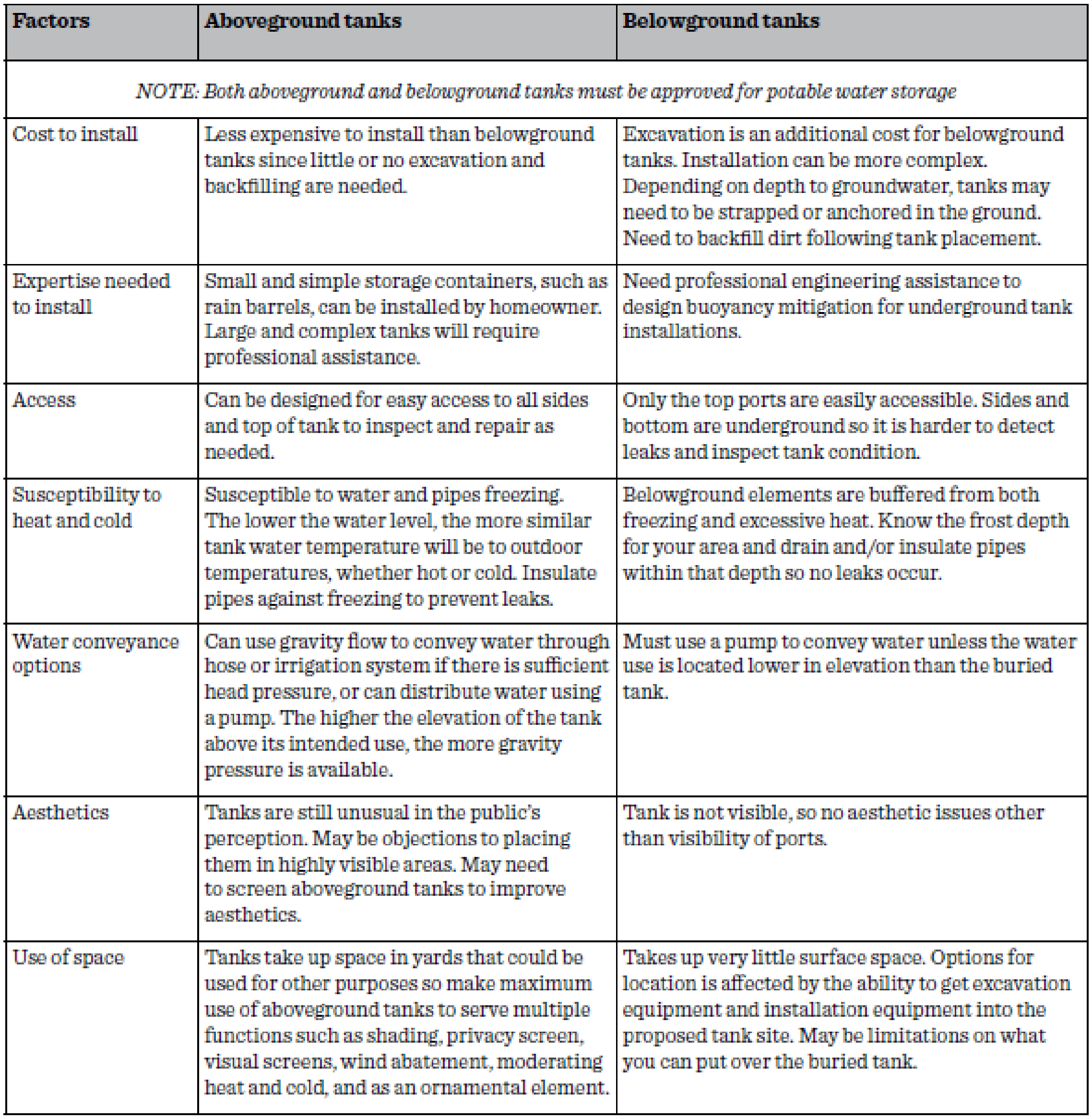


Below Ground System



Above Ground System

Comparison of characteristics of aboveground tanks and belowground tanks



Factors	**Aboveground tanks**	**Belowground tanks**
NOTE: Both aboveground and belowground tanks must be approved for potable water storage		
Cost to install	Less expensive to install than belowground tanks since little or no excavation and backfilling are needed.	Excavation is an additional cost for belowground tanks. Installation can be more complex. Depending on depth to groundwater, tanks may need to be strapped or anchored in the ground. Need to backfill dirt following tank placement.
Expertise needed to install	Small and simple storage containers, such as rain barrels, can be installed by homeowner. Large and complex tanks will require professional assistance.	Need professional engineering assistance to design buoyancy mitigation for underground tank installations.
Access	Can be designed for easy access to all sides and top of tank to inspect and repair as needed.	Only the top ports are easily accessible. Sides and bottom are underground so it is harder to detect leaks and inspect tank condition.
Susceptibility to heat and cold	Susceptible to water and pipes freezing. The lower the water level, the more similar tank water temperature will be to outdoor temperatures, whether hot or cold. Insulate pipes against freezing to prevent leaks.	Belowground elements are buffered from both freezing and excessive heat. Know the frost depth for your area and drain and/or insulate pipes within that depth so no leaks occur.
Water conveyance options	Can use gravity flow to convey water through hose or irrigation system if there is sufficient head pressure, or can distribute water using a pump. The higher the elevation of the tank above its intended use, the more gravity pressure is available.	Must use a pump to convey water unless the water use is located lower in elevation than the buried tank.
Aesthetics	Tanks are still unusual in the public's perception. May be objections to placing them in highly visible areas. May need to screen aboveground tanks to improve aesthetics.	Tank is not visible, so no aesthetic issues other than visibility of ports.
Use of space	Tanks take up space in yards that could be used for other purposes so make maximum use of aboveground tanks to serve multiple functions such as shading, privacy screen, visual screens, wind abatement, moderating heat and cold, and as an ornamental element.	Takes up very little surface space. Options for location is affected by the ability to get excavation equipment and installation equipment into the proposed tank site. May be limitations on what you can put over the buried tank.

APPENDIX B

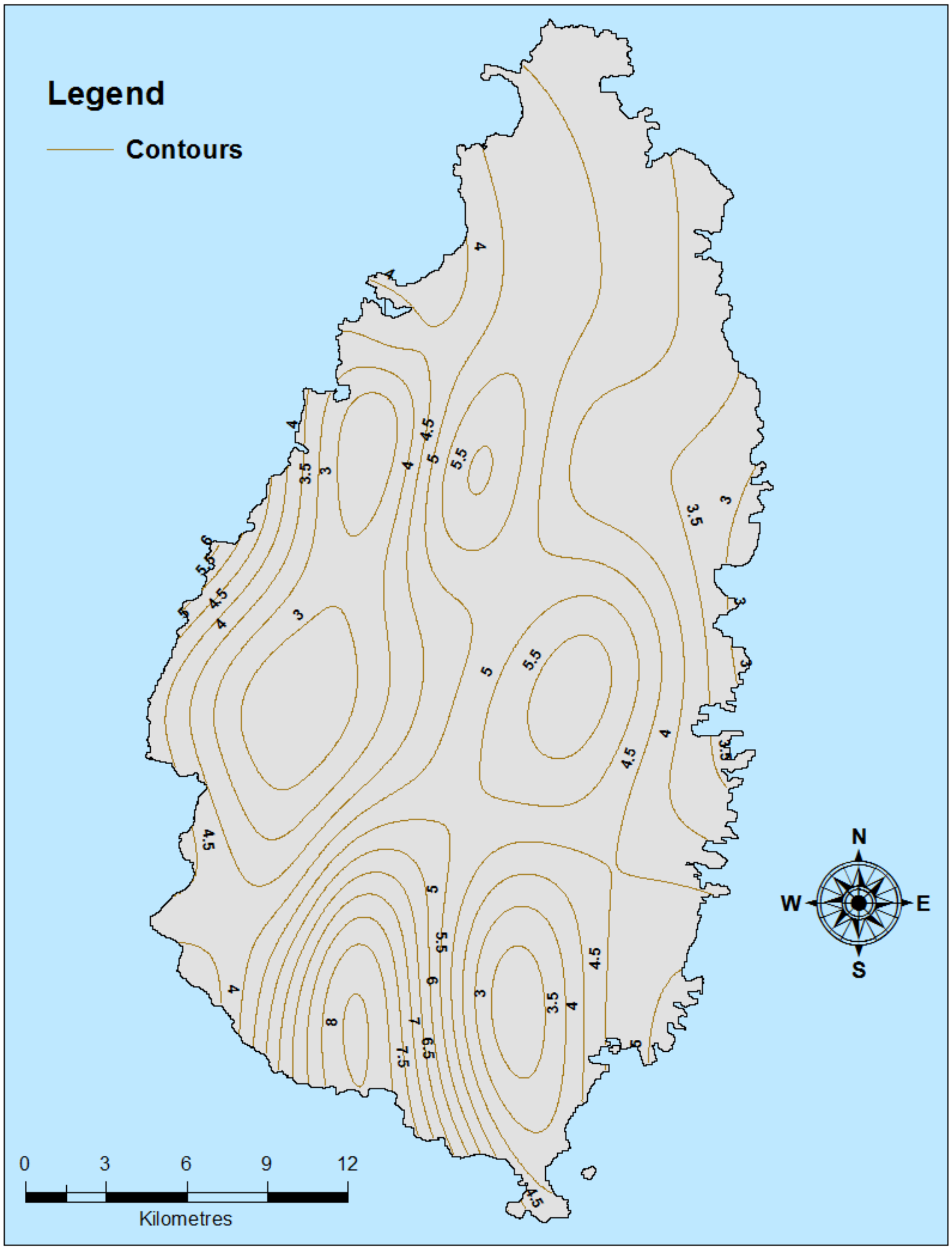
Design Specifications for Rainwater Harvesting Systems

Listing of basic materials of a designed rainwater harvesting system

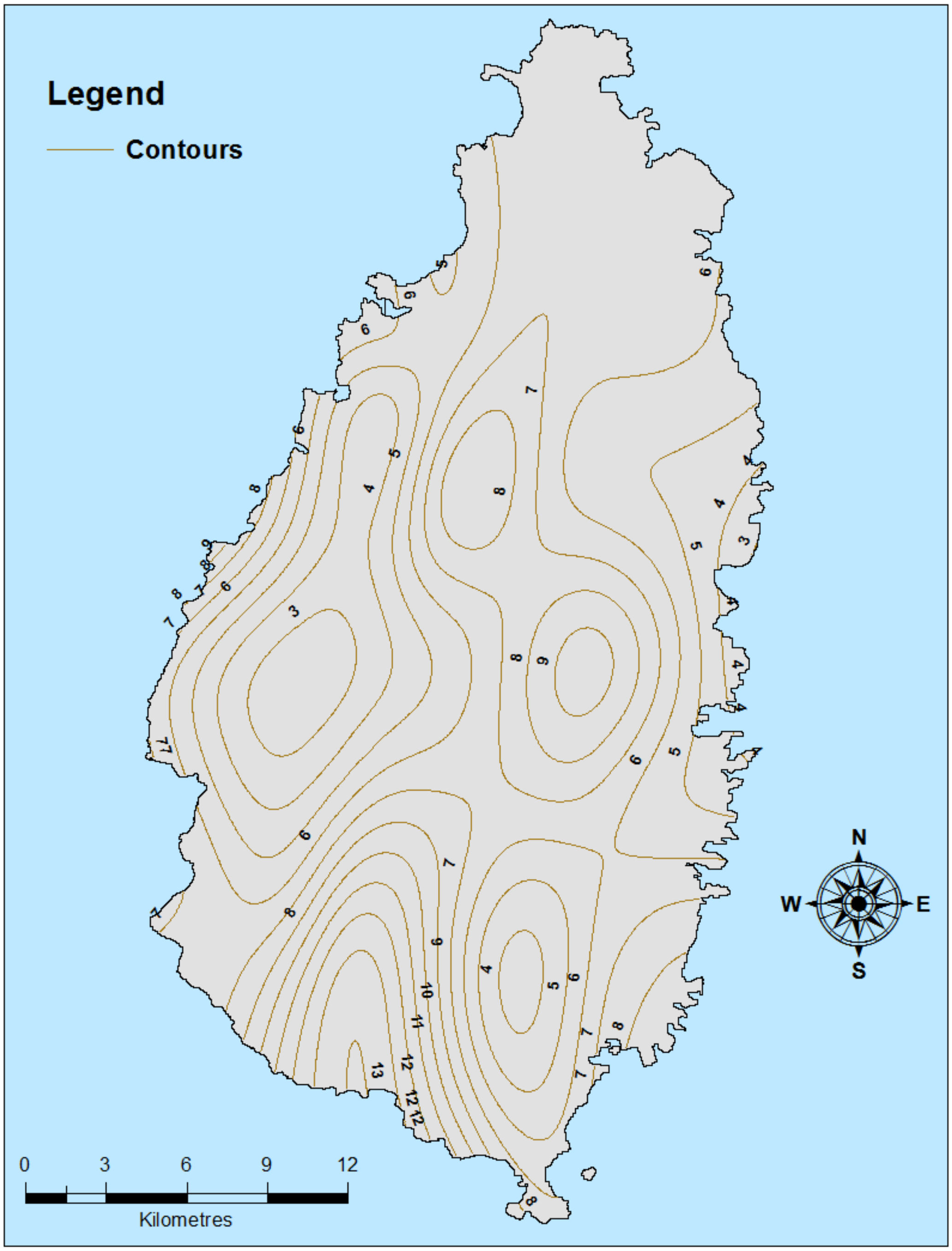
Item	Specification
Gutters and Downspouts	Materials commonly used for gutters and downspouts include polyvinylchloride (PVC) pipe, vinyl, aluminum, and galvanized steel. Lead must not be used as gutter and downspout solder, since rainwater can dissolve the lead and contaminate the water supply. ▪ The length of gutters and downspouts is determined by the size and layout of the catchment and the location of the cisterns. ▪ Be sure to include needed bends and tees.
Pretreatment	At least one of the following (all rainwater to pass through pretreatment): ▪ First flush diverter ▪ In-ground filter ▪ In-tank filter ▪ Hydrodynamic separator ▪ Roof washer ▪ Leaf and mosquito screen (1 mm mesh size) For large tanks (10m3) the tanks should have a settling compartment for sediment removal
Cisterns	▪ Materials used to construct cisterns must be structurally sound. ▪ Cisterns should be constructed in areas of the site where soils can support the load associated with stored water. ▪ Cisterns must be watertight and sealed using a water-safe, non-toxic substance. ▪ Cisterns must be opaque or otherwise shielded to prevent the growth of algae. ▪ Previously used containers to be converted to rainwater storage tanks should be fit for potable water or food grade products ▪ Cisterns above ground or below ground must have a lockable opening of at least 450mm in diameter ▪ The size of the rainwater harvesting system(s) is determined through design calculations.

APPENDIX C

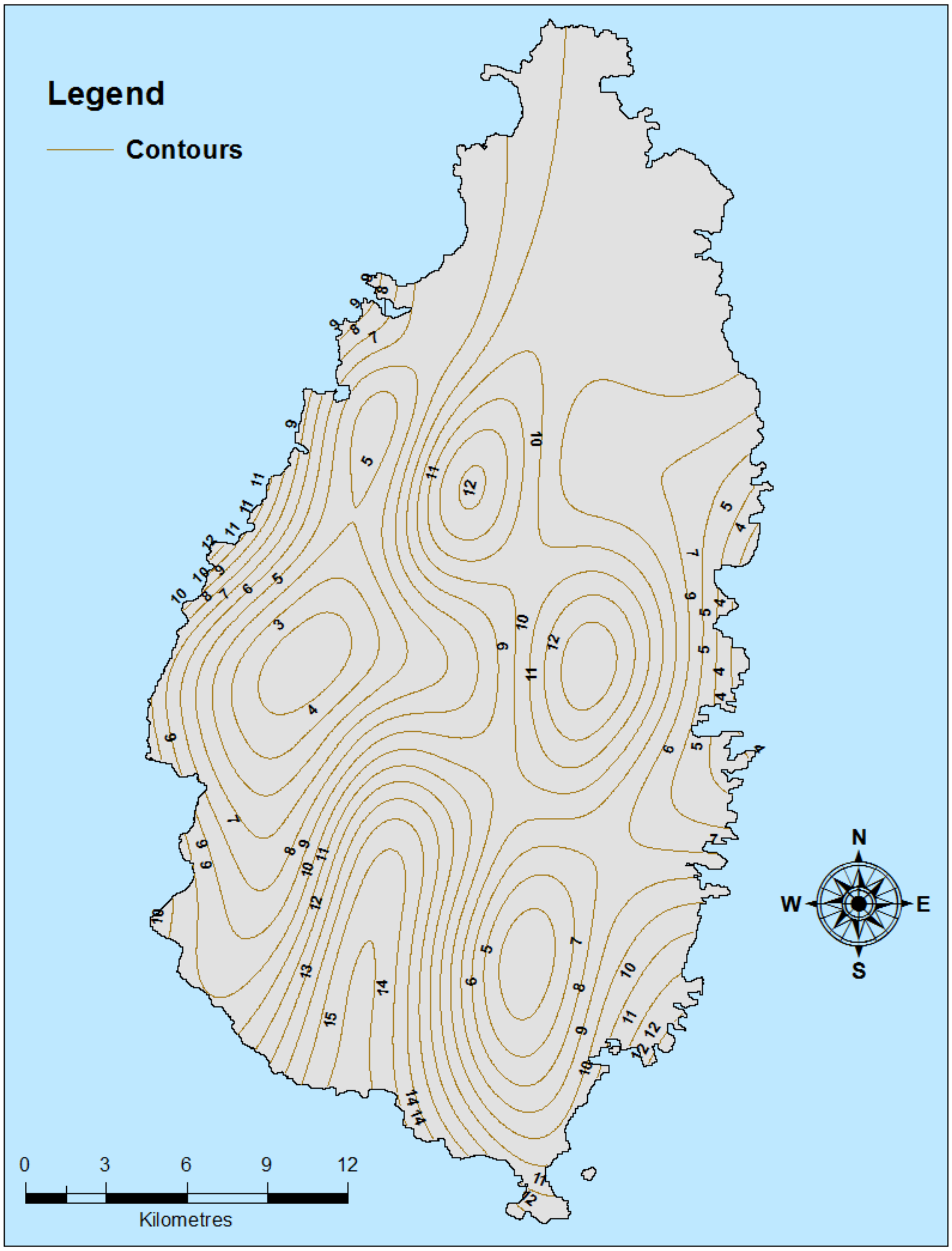
Rainfall Intensity Maps for St. Lucia for T = 2, 5, 10, 25 and 50 years



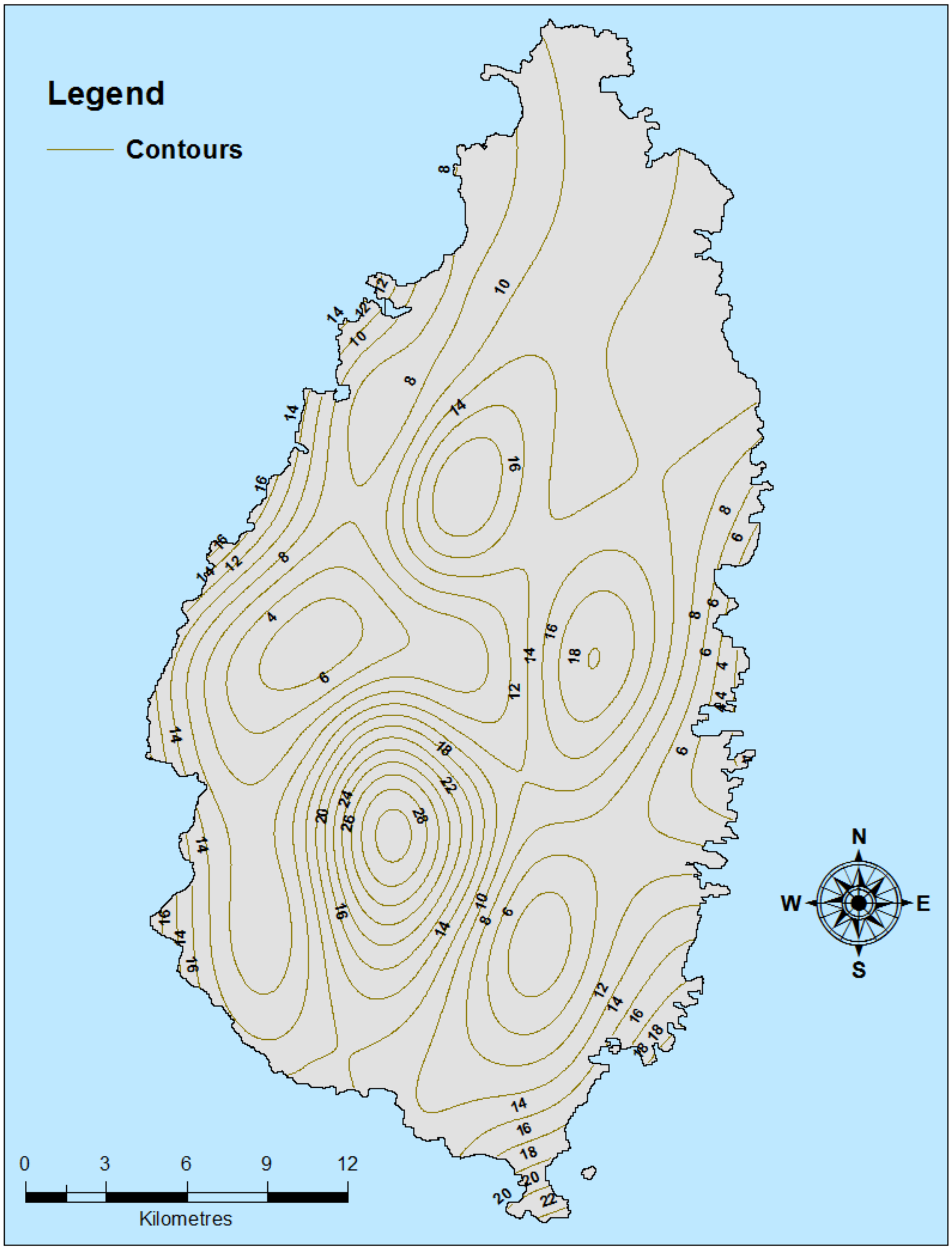
24 hr rainfall intensity (mm/hr) map for Saint Lucia (T = 2yr)



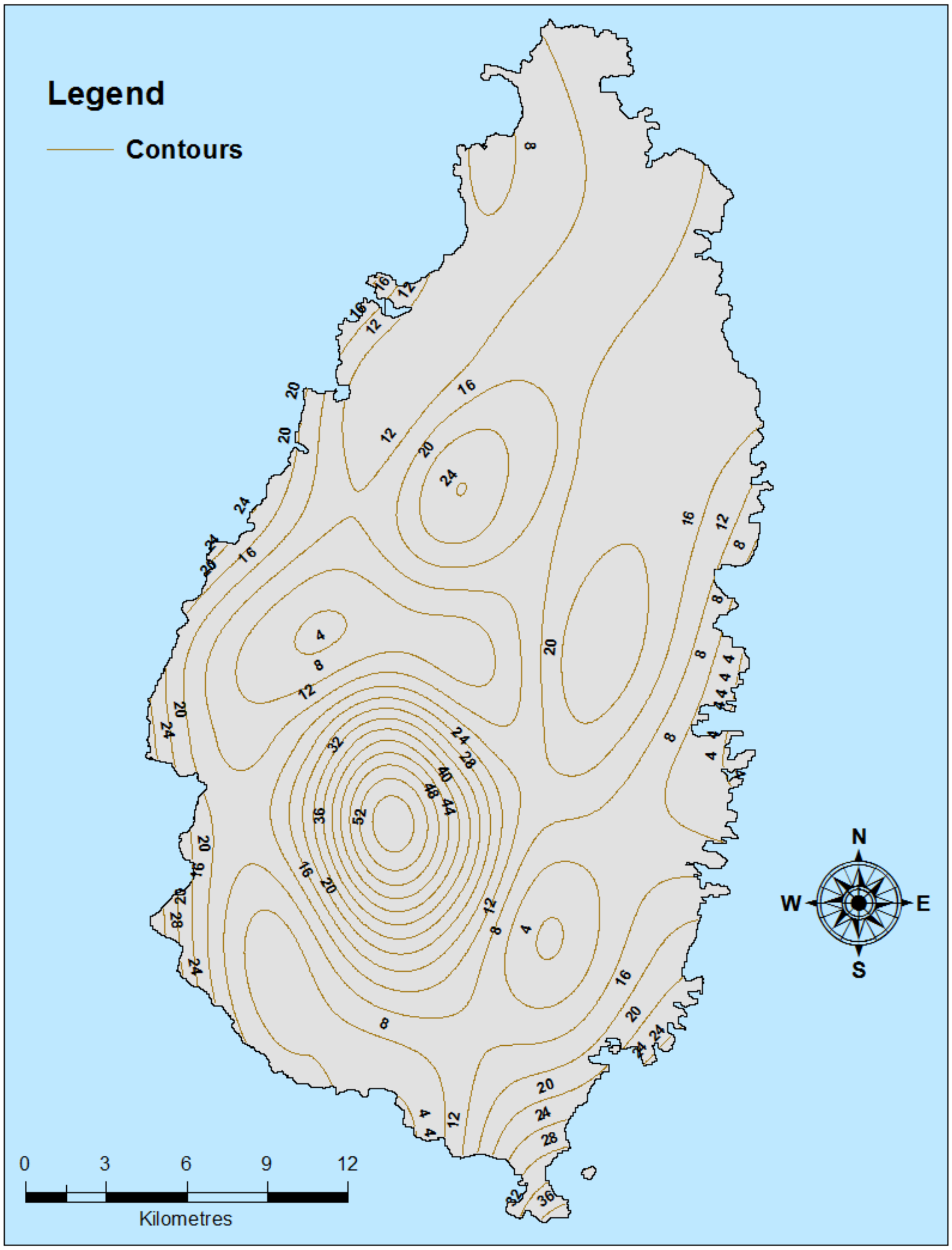
24 hr rainfall intensity (mm/hr) map for Saint Lucia (T = 5yr)



24 hr rainfall intensity (mm/hr) map for Saint Lucia (T = 10yr)



24 hr rainfall intensity (mm/hr) map for Saint Lucia (T = 25yr)

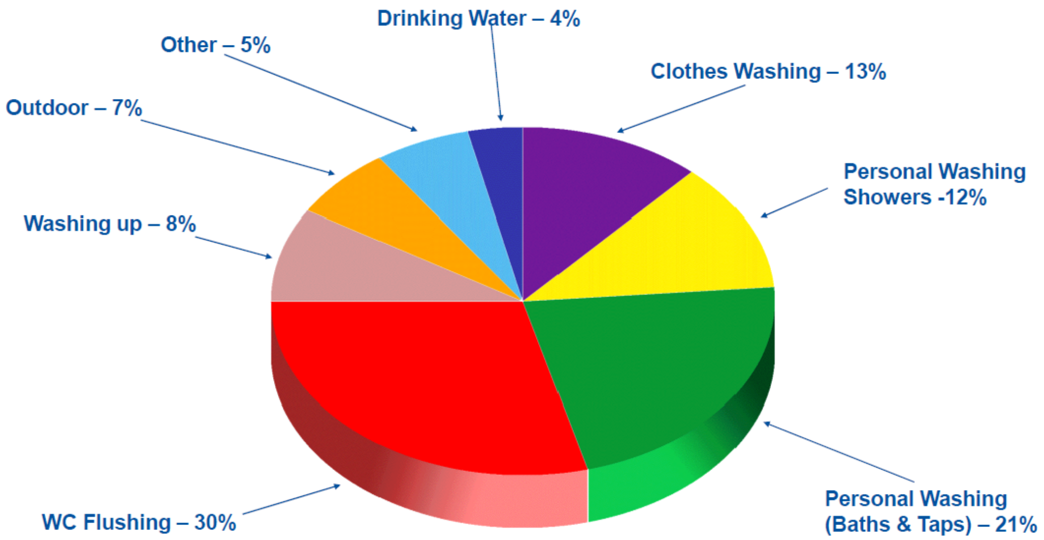


24 hr rainfall intensity (mm/hr) map for Saint Lucia (T = 50yr)

APPENDIX D

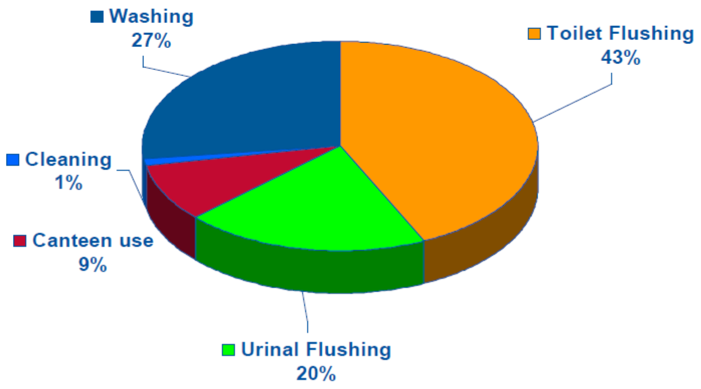
Rainwater Harvesting Calculator

Uses for harvested rainwater water in domestic buildings



Uses for Harvested Rainwater in Commercial Buildings

In some commercial applications, up to 80% of the potable water used can be substituted with harvested rainwater



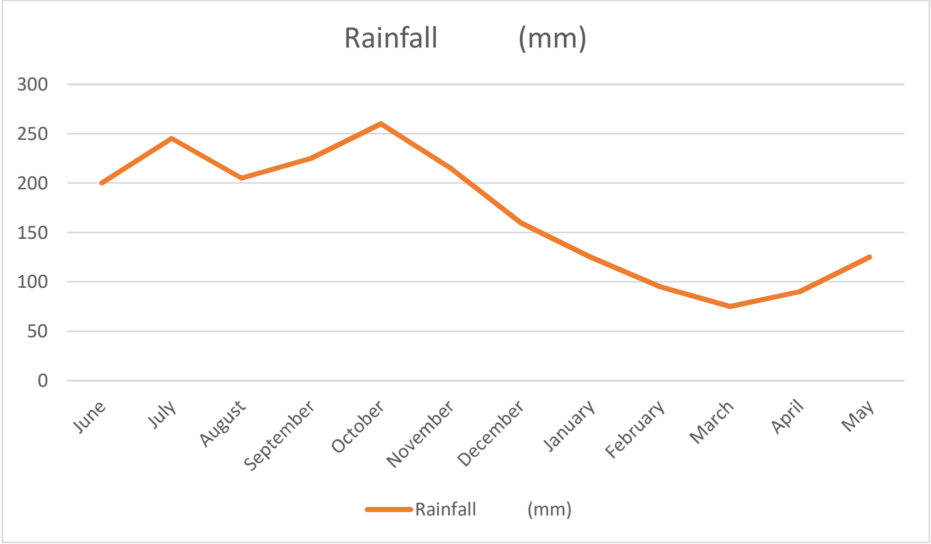
ESTIMATING INDOOR DAILY DOMESTIC DEMAND

Facility	Toilets (use only the appropriate type)		Baths & Showers			Appliances or uses which are measured on a per-use basis (not a per-person basis)			TOTAL
	Ultra-Low Flush Toilets (ULFT)	**.6Dual Flush**	**Shower head**	**Baths**	**Faucets (personal hygiene, cooking and cleaning of surfaces)**	**Clothes washer front loading (horizontal axis)**	**Dish washer**	**Misc. other**	
Water consumption using conserving fixtures A	1.6 gal/flush	1.6 gal/flush Liquids or solids	2.2 gal/min	50 gal/bath	2.2 gal/faucet/ min	18-25 gal/load	8 gal/cycle		
Assumptions from AWWA Residential End-Use Study (person/day) B	6 flushes/person /day	6 flushes/perso n/day	5 min/person /day	N/A	5 min/person /day	2.6 loads/week	0.7 cycles/day		
Adjustments to assumptions (adjust up or down according to actual usage) C									
Number of persons in the household D									
Household monthly demand **A x (B or C) x D x 30**									

RAINWATER STORAGE CALCULATOR

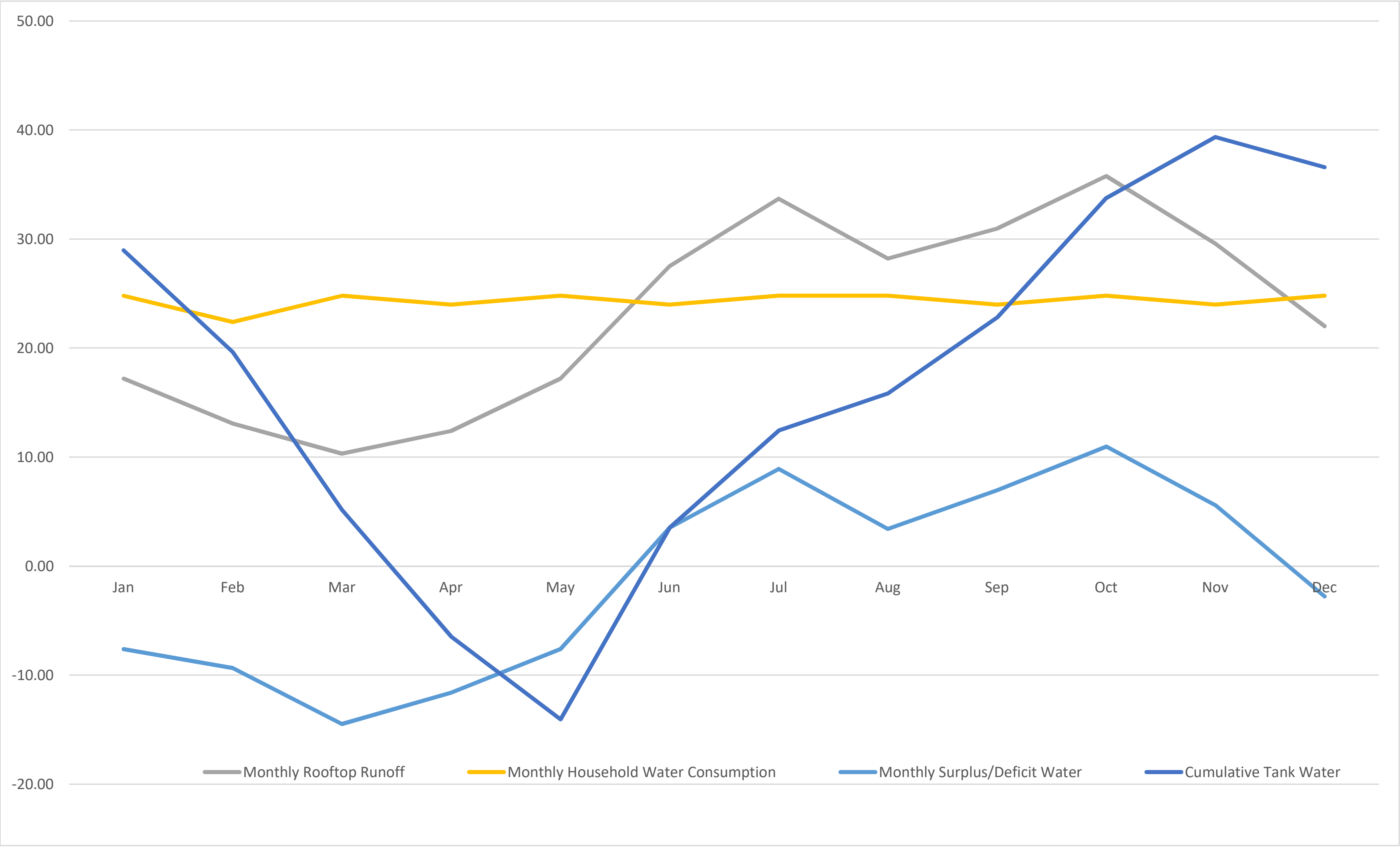
Variables	Units	INPUT
Collection Efficiency		0.8
Run-off Coefficient		0.8
Rooftop Area	m^2	215
Number of People	people	4
Daily Water Use per Person	L/day	200
Required Tank Capacity	m^3	40.00

Month	Days in the Month	Rainfall (mm)	Monthly Water Yield (litres) A	Cumulative Water Yield (litres) B	Monthly Water Demand (litres) C	Cumulative Water Demand (litres) D	Volume Stored (litres) B - D	Monthly Deficit/Surplus (litres) A - C
June	30	200	27520	27520	24000	24000	3520	3520
July	31	245	33712	61232	24800	48800	12432	8912
August	31	205	28208	89440	24800	73600	15840	3408
September	30	225	30960	120400	24000	97600	22800	6960
October	31	260	35776	156176	24800	122400	33776	10976
November	30	215	29584	185760	24000	146400	39360	5584
December	31	160	22016	207776	24800	171200	36576	-2784
January	31	125	17200	224976	24800	196000	28976	-7600
February	28	95	13072	238048	22400	218400	19648	-9328
March	31	75	10320	248368	24800	243200	5168	-14480
April	30	90	12384	260752	24000	267200	0	-11616
May	31	125	17200	277952	24800	292000	0	-7600
TOTAL		**2020**			**292000**			**-14048**



Month	Units	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Days in Month	days	31	28	31	30	31	30	31	31	30	31	30	31
Monthly Rainfall	mm/month	125	95	75	90	125	200	245	205	225	260	215	160
Monthly Rooftop Runoff	m^3/month	17.20	13.07	10.32	12.38	17.20	27.52	33.71	28.21	30.96	35.78	29.58	22.02
Monthly Household Water Consumption	m^3/month	24.8	22.4	24.8	24.0	24.8	24.0	24.8	24.8	24.0	24.8	24.0	24.8
Monthly Surplus/Deficit Water	m^3/month	-7.60	-9.33	-14.48	-11.62	-7.60	3.52	8.91	3.41	6.96	10.98	5.58	-2.78
Cumulative Tank Water	m^3/month	28.98	19.65	5.17	-6.45	-14.05	3.52	12.43	15.84	22.80	33.78	39.36	36.58

GRAPHICAL REPRESENTATION



APPENDIX E

Sustainable Design Criteria

There are 10 very important steps to follow to ensure sustainable rainwater harvesting system designs. These 10 steps are as follows:

1. **Ensure that the roof surface is suitable for collecting quality rainwater :** Colorbond and Zincalume steel sheets, well fired glazed tiles, concrete/cement tiles, clay tiles and composite tiles are popular choices for rainwater collection. If water is intended for drinking-: (a) contact the manufacturer to confirm whether the roofing material is suitable for potable water collection, and (b) ensure all pipes and fittings used within the system are also approved. Lead based materials must be avoided at all times and corroded roofs needs to be repaired or replaced. They may occur where galvanized roofs have been installed and react with screws and fittings from other fixtures that have been installed on the roof. Also painted roofs should be examined to ascertain that non-toxic acrylic based paints were used and not paints containing lead, chromate, tar/bitumen, fungicides or other toxins that may pose a health risk and/or impart and unpleasant taste and odour to the water. Lastly, for freshly painted roofs, runoff water from the first rainfall should be diverted away form the storage tank so as to avoid a taste and odour problem.

2. **Install gutters to standards :** Ensure roof gutters are installed to the appropriate standards and building codes with the regulation fall to the outlets. Gutters that pond water creates a potential mosquito breeding habitat and can be an incubator for bacteria. Gutters must be installed with a fall of no less than 1:500 for eaves gutters (unless fixed to metal fascias), and 1:100 for box gutters.

Roof Area served by One Gutter (m^2)	Gutter Width (mm)	Minimum Downpipe Diameter (mm)
17	60	40
25	70	50
34	80	50
46	90	63
66	100	63
128	125	75
208	150	90

Table E1 – Guide to sizing gutters and down-pipes for RWH systems in tropical regions

Table 4 gives a guide to the sizing of gutters and downpipes especially for tropical regions where the choice of materials can be either PVC or color coated Aluzinc. Roof gutters need to be kept free of leaves and debris to maximize rainwater yield. Clogged roof gutters will prevent water from flowing to the tank and can reduce water quality by making it acidic through leaves and debris breaking down in the gutter. If you have overhanging trees, you may need to pay more attention to the cleaning of your gutters.

3. **Install a fire proof gutter mesh system to prevent leaves and debris from blocking gutters :** Screening material MUST be fire proof and allow maximum sunlight into the roof gutter system. Screening material must NOT be too fine or create a shade house for spiders.

4. **Fit gutter outlets on the underside of the roof gutter to minimise sludge build up :** Gutter outlets fitted from inside the roof gutter create a lip of up to 4mm at the water outlet point. This means water ponds, causing a build-up that will hold a rage of bacteria and pollutants. By fixing gutter outlets on the underside of the gutter there is no obstruction to water flow and the roof gutters drain out. Dry gutters last longer and eliminate a breeding ground for mosquitoes.

5. **Fit rain heads to downpipes to divert leaves and debris :** Rain heads direct leaves and larger debris out of the flow of the water. The type of rain head that is required depends on the type of system. Multiple screen rain heads are best. “Wet” systems require rain heads to be fitted with screens that are mosquito proof (<1mm apertures). Rain heads that screen the larger material onto the ground are better than “junk basket” types.

6. **Prevent insect entry :** Fit insect proof screens to all pipes that hold water (“wet” systems) and all pipes and openings to/from your tank. Mosquitoes spread diseases at an alarming rate and breed in water. Ensure multiple screen rain heads are installed at the entry point of gutter downpipes. Fit insect proof flap valves or screens to the end of the pipe system at the entry to the rainwater tank, and to the overflow from the tank. They should be vented so as to allow a flow of air/oxygen over the surface of the water thus improving its aerobic content. This also prevents a vacuum when large quantities of water are quickly drawn off from the tank. Flap valves should have double seals, be self-cleaning, and have a flap that cannot be over rotated and left open.

7. **Fit appropriately sized first flush water diverter/s :** This is a critical factor in achieving good quality water. First Flush water diverters prevent the first, most contaminated rainwater from entering the tank (See Figure 9) and should be installed just prior to the point of entry into the tank.

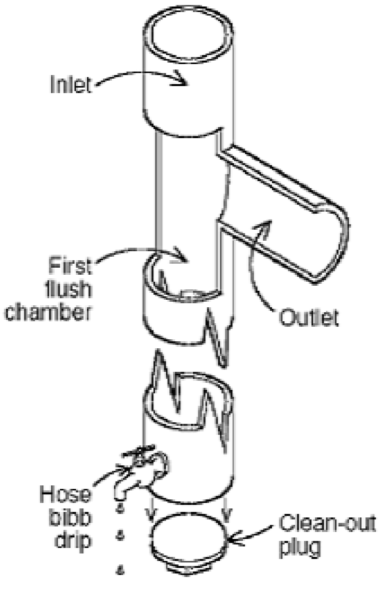


Figure E1 – Schematic diagram of a first-flush diverter

The recommended volume to be diverted is based on an assessment of (1) roof area, and (2) a pollution factor (between 0.5 – 2 litres of water per m^2 or 0.009 – 0.04 gallons per ft^2 of roof area). The volume, type of downpipe system, and site characteristics will determine the type of water diverter required. Water diverters with a variable volume chamber are better than "fixed volume" diverters, because they can be customized to the specific requirements of each site. For best results with a "wet" system, the volume held in the pipes should be added to the roof diversion quantity. For a typical household roof, the optimum capacity of a first flush device should be 20 liters or 4.4gallons. However, it must be noted that the first flush diverts needs to be emptied out following every rainfall event utilizing the hose bib at the bottom of the device. Failure to do so can lead to contamination of the system at the next rainfall event as contaminated water will not be flushed away and will flow into the tank.

It is generally assumed that a depth of rainfall on the roof equivalent to 0.50 mm is required to wash off the accumulated contaminants and debris. You first need to determine the area of the roof and simply multiply by 0.50mm. Secondly, to determine the length of first-flush down-pipe diversion requires you divide the required volume of water to be diverted, by the cross-sectional area of the pipe (πr2), where π = 3.14 and r is the radius or half the diameter of the pipe.

Vol. of diverted water (liters) = house length (m) x house width (m) x 0.5 (mm)
(multiply answer by 0.22 to convert the value to imperial gallons)

Pipe length (m) = Vol. of diverted water (l) ÷ [3.14 x r^2 (mm) x 0.001]
Pipe length (feet) = Vol. of diverted water (gal) x 22.57 ÷ [3.14 x r^2 (inch)]

A worked example:

Roof length = 8 meters
Roof width = 5 meters
Pipe diameter = 150 mm (6 inches), therefore radius = 75 mm (3 inches)

Volume of diverted water (liters)= 8 x 5 x 0.5 = 20 liters (or 4.4. gallons)
Pipe length (m)=20 ÷ [3.14 x 75^2 x 0.001] = 1.13 m
Pipe length (ft) = 4.4 x 22.57 ÷ (3.14 x 32) = 3.51 ft

8. **Select an appropriate water tank, tank 'top-up' and pump system :** Another critical component of the system is the tank. A minimum standard of quality is recommended for all rainwater tanks to ensure tanks are structurally sound, safe and reliable for long term rainwater storage. The different types of tanks that are available are (1) polyethylene tanks, (2) steel tanks, (3) concrete tanks and (4) bladder tanks. For polyethylene tanks, these are readily available commercial and range in sizes from 455 litres (100 gallons) to 455,000 litres (10,000 gallons). Concrete tanks and steel tanks on the other hand whereas they are readily available commercially they must be designed by a suitably qualified Structural Engineer. Lastly, bladder tanks are also available commercially but must be purchased from specialty manufactures as they are not available "off the shelf". As indicated earlier the tank size would have been determined

based on annual rainfall, roof catchment area and water usage and for which they can be above ground or under ground and have various advantages and disadvantages as seen in Table 5.

	Advantages	Disadvantages
Above-Ground	• Allows for easy inspection for cracks (masonry structures) or leakage • Cheaper to install and maintain; particularly the case for small volume household supply needs • Water extraction can be done by gravity with extraction by a tap and allows for easy draining if needed • Tanks(s) can be raised above ground to increase water pressure	• Requires space for installation, particularly if large storage volume is needed; case for commercial and industrial users • Masonry works exposed to deterioration from weathering • Failure of elevated support structures can be dangerous • Requires the construction of a solid foundation which may be costly
Underground	• Surrounding ground lends structural support allowing lower wall thickness and lower installation costs • Can form part of the building foundation • Unobtrusive – requires little or no space above ground; useful where large volume storage is required	• For relatively small storage requirements, is relatively more expensive • Water extraction is more problematic and requires a pump • Leaks or failures are difficult to detect; pose risk to building foundation failure if constructed on a slope • Possible contamination of the tank from groundwater intrusion or floodwaters • Possibility of undetected structural damage by tree roots; allows for entry of contaminants or vermin • Cannot be easily drained for cleaning, requires pump-out

Table E2 - Advantages and disadvantages of aboveground and underground storage systems

The storage facility is at the core of the RWH system. In addition to having the appropriate volume capacity in relation to the catchment area, rainfall conditions and needs, it must be functional, durable and cost-effective in its installation and maintenance. An ideal or ‘universal’ storage tank design does not exist; selection of the type of storage facility ultimately depends on purpose of use, affordability, availability of supplies and materials, and know-how in design and installation. There are also advantages and disadvantages of typical tank materials as seen in Appendix G. The following are key considerations in design and operation of the storage facility:

- The rainwater pump should draw water from the opposite side of the tank to the inlet from the roof catchment. The inlet and outlet points of the tank should be on opposite ends of each other;

- The tank overflow capacity must be equal to or greater than the capacity of the inflow so as to avoid overtopping and localized flooding in the area where the tank is installed;
- Water-tight construction with a secure cover to keep out insects and other vermin, dirt and sunshine (note, exposure to sunlight will cause algal growth in stored water);
- Screened inlet to prevent particles and mosquitoes from entering the tank;
- Screened overflow pipe to prevent mosquito entry and breeding;
- The rainwater tank outlet should be 50 mm (2 inches) or higher from the base of the tank to ensure the outlet does not access material that may have built up on the bottom of the tank. This material plays an important role in the natural water treatment train of a water tank;
- In the case where a submersible pump is used in the rainwater harvesting system, the inlet to the submersible pump should be located in the tank at either 50 mm (2 inches) or 100 mm (4 inches) above the base of the tank, for the same reasons;
- In the case of cisterns, inclusion of a manhole (to permit insertion of a ladder) to allow access for cleaning;
- An extraction system that does not contaminate the water during operation (related to tap and pump installation);
- Soak away to prevent spilt water forming standing puddles near the tank (minimize mosquito breeding);
- In the case of cisterns, a maximum height of 2 meters (related to water depth) to prevent buildup of high water pressure (unless additional reinforcement is used in walls and foundations)
- For optimal water quality ensure the rainwater from the tank is regularly used.

Utilise a dual water supply system (if required) to automatically ‘top-up’ the tank with the mains water when tank water levels fall to a designated minimum level. Select a pump system (if required) to distribute water for use inside or outside the home. In order to estimate the pump size, we need to understand the flow rates required for house use. The flow rate guide below provides an indication of the flow rate that the pump may need to supply.

ITEM	FLOW RATE Liters/Minute (gal/min)
Toilet	5 (1.1)
Washing Machine	12 (2.6)
Hot Water (Shower)	9 (2.0)
Garden Hose	15 (3.3)

Table E3 – Flow rate guide for various appliances and fixtures

As a guide you should assume two appliances could be operating at the one time. An industry standard for the pressure provided by the pump should be greater than 300 KPa (43.5psi). A pumping system can also be installed on a rainwater tank to increase the water pressure to be used for garden watering, inside the house for the toilet, washing machine, or whole of house. Some water appliances will not work unless there is pressure produced by the pump. The pump can be installed outside (external pump) or inside (in-tank pump) the rainwater tank (See Figure 10).

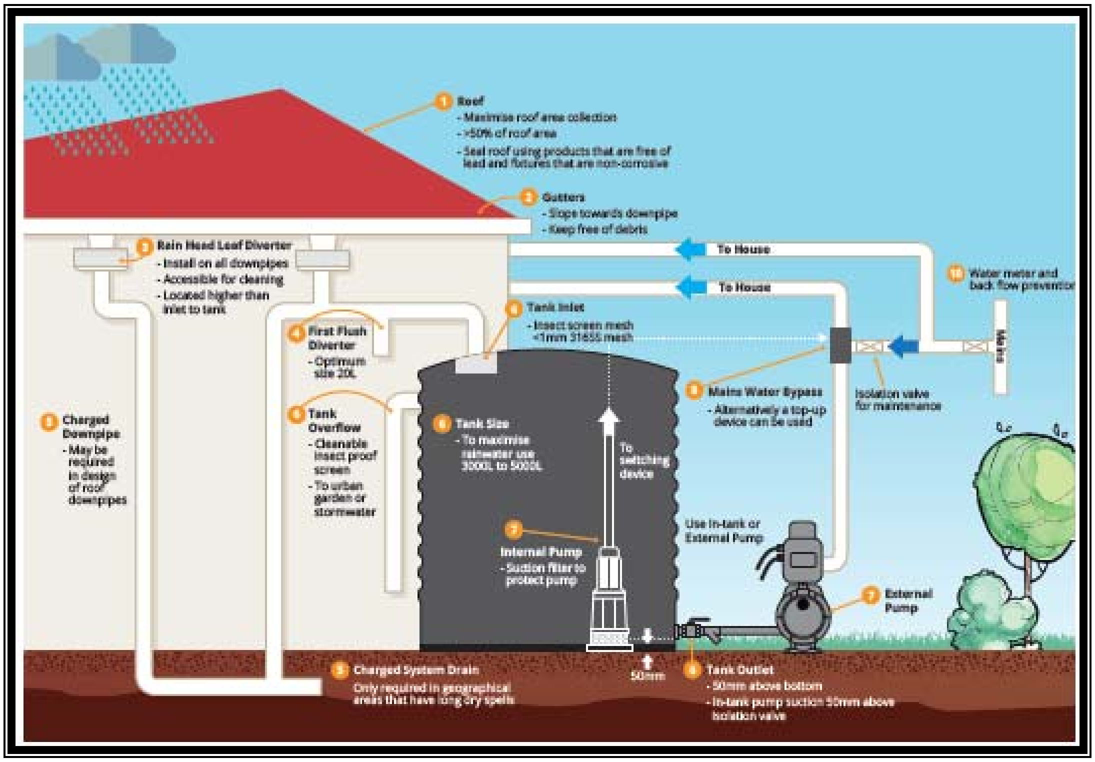


Figure E2 – External and internal options for locating a water pump on a RWH system

However, there are advantages and disadvantages of where the pump is located. As such a guide to the benefits of an external pump and an in-tank pump are listed below in Table 7.

Characteristic	External Pump	In-tank Pump
Performance	Ensure correctly installed suction line	Ensure inlet screen of pump is located 50mm above bottom of tank
Noise	May require positioning away from bedrooms or install pump cover.	Water in tank will minimize noise
Electrical cabling	Ensure electrical cables are protected from children and animals	Power point should be installed on wall at level of top of tank so cabling is out of reach
Weather protection	Ensure protection from sun and rain by using pump cover	No protection required

Table E4 – Benefits of external and in-tank pumping systems

9. **Draw water for usage from the aerobic zone :** The closer the usage draws off point is to the top of the tank (aerobic zone) the better the quality of water. The best system has two outtake points – one 1/3 the way up the tank for use inside the home, and the other

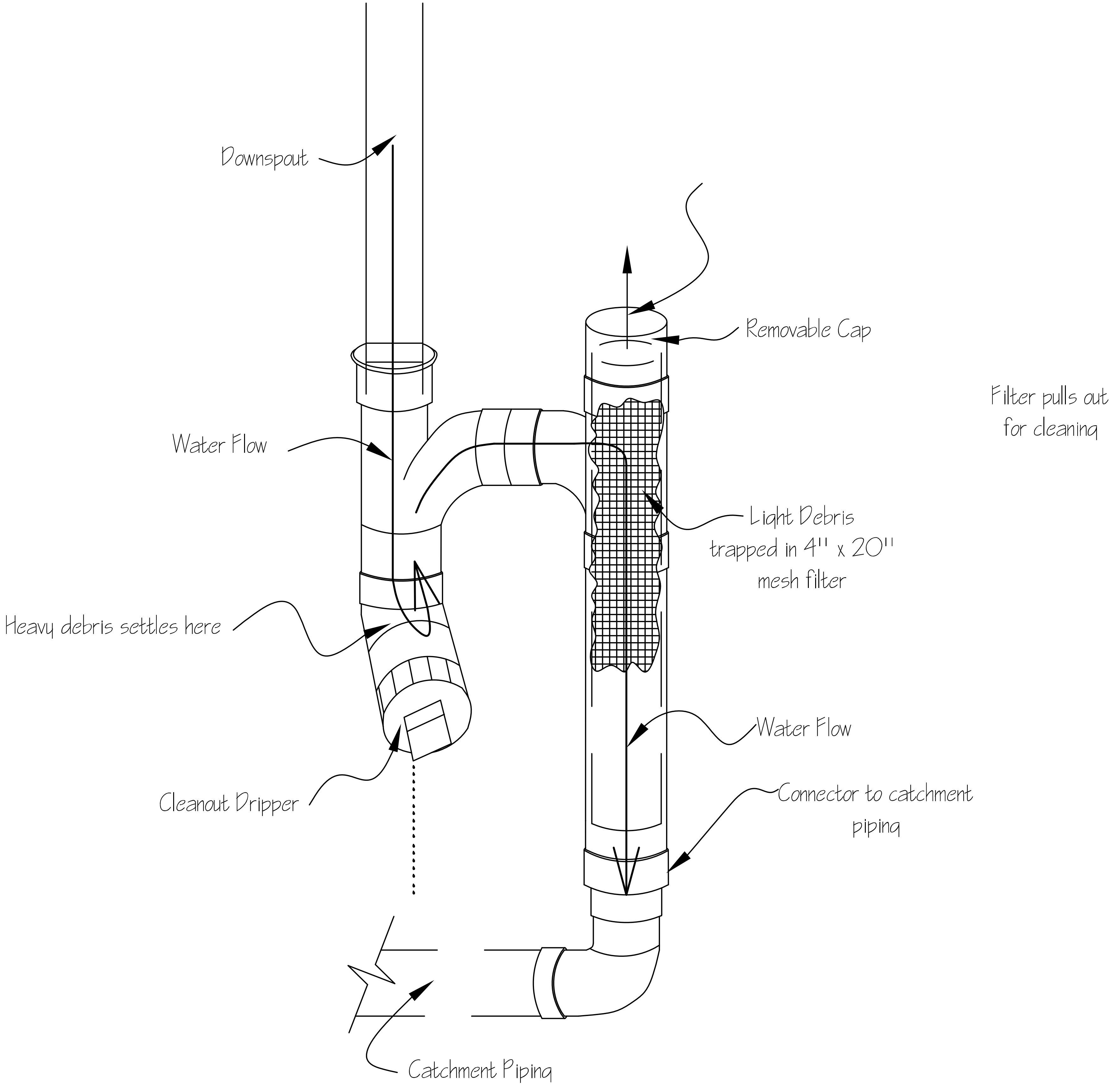
at the bottom of the tank (in the anaerobic zone) for use outside the home and overflow. The outlet pipe at the bottom of the tank should be no lower than four (4) inches above the floor of the tank as water below this level is considered to be dead water. Tank overflows that simultaneously take excess water and vacuum out sludge from the bottom of the tank are best.

10. **Ensure the system is maintained :** This is one of the most important factors in ensuring good quality water. All components, including gutters, rain heads, water diverters and water tanks, should be serviced regularly.

APPENDIX F

High Volume First Flush Diverter Diagram

High Capacity Debris Trap/ Filter



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Notes

No.	Initial	Revision/Issue	Date

Project Title:
Rainwater Harvesting

Drawing Title:
First Flush Diverter/Debris Trap Filter Details

Date: August 2018
Project No: DVRP-RWH-18
Scale: Not to scale
Drawn By: L. Arnold
Drawing No: RWH-01
Checked By: L. Arnold

Designed By: L. Arnold

APPENDIX G

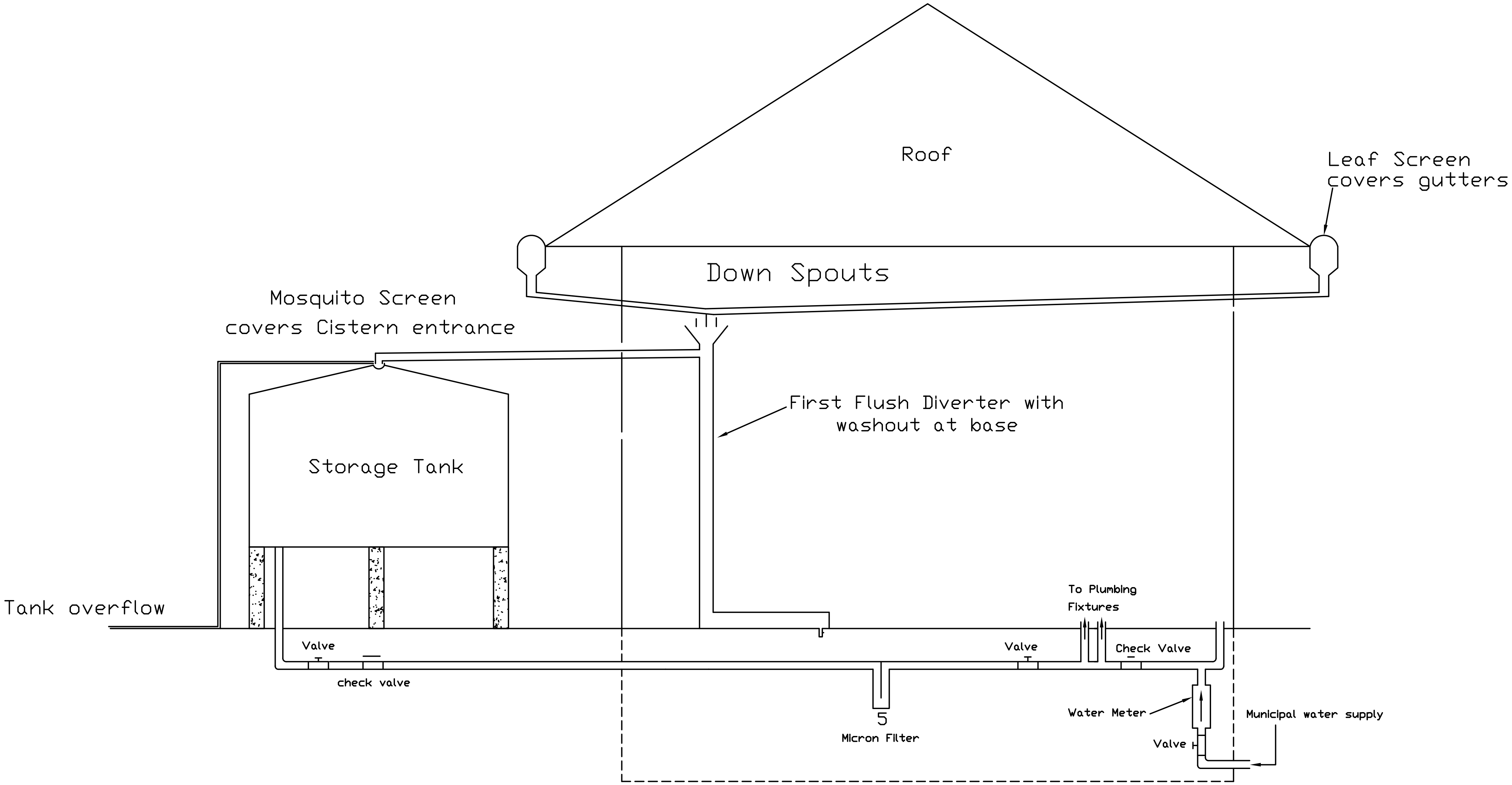
Advantages and Disadvantages of Typical Cistern Materials

Advantages and Disadvantages of Typical Cistern Materials

Cistern Material	Advantages	Disadvantages
Fiberglass	Commercially available, alterable and moveable; durable with little maintenance; light weight; integral fittings (no leaks); broad application	Must be installed on smooth, solid, level footing; pressure proof for below-ground installation; expensive in smaller sizes
Polyethylene	Commercially available, alterable, moveable, affordable; available in wide range of sizes; can install above or below ground; little maintenance; broad application	Can be UV-degradable; must be painted or tinted for above-ground installations; pressure-proof for below- ground installation
Modular Storage	Can modify to topography; can alter footprint and create various shapes to fit site; relatively inexpensive	Longevity may be less than other materials; higher risk of puncturing of watertight membrane during construction
Plastic Barrels	Commercially available; inexpensive	Low storage capacity (20 to 50 gallons); limited application
Galvanized Steel	Commercially available, alterable, and moveable; available in a range of sizes; film develops inside to prevent corrosion	Possible external corrosion and rust; must be lined for potable use; can only install above ground; soil pH may limit underground applications
Steel Drums	Commercially available, alterable, and moveable	Small storage capacity; prone to corrosion, and rust can lead to leaching of metals; verify prior to reuse for toxics; water pH and soil pH may also limit applications
FerroConcrete	Durable and immoveable; suitable for above or below ground installations; neutralizes acid rain	Potential to crack and leak; expensive
Cast-in-Place Concrete	Durable, immoveable, and versatile; suitable for above or below ground installations; neutralizes acid rain	Potential to crack and leak; permanent; will need to provide adequate platform and design for placement in clay soils
Stone or Concrete Block	Durable and immoveable; keeps water cool in summer months	Difficult to maintain; expensive to build

APPENDIX H

Connection Schematics



Note : Disinfection is done manually at the storage tank using household bleach

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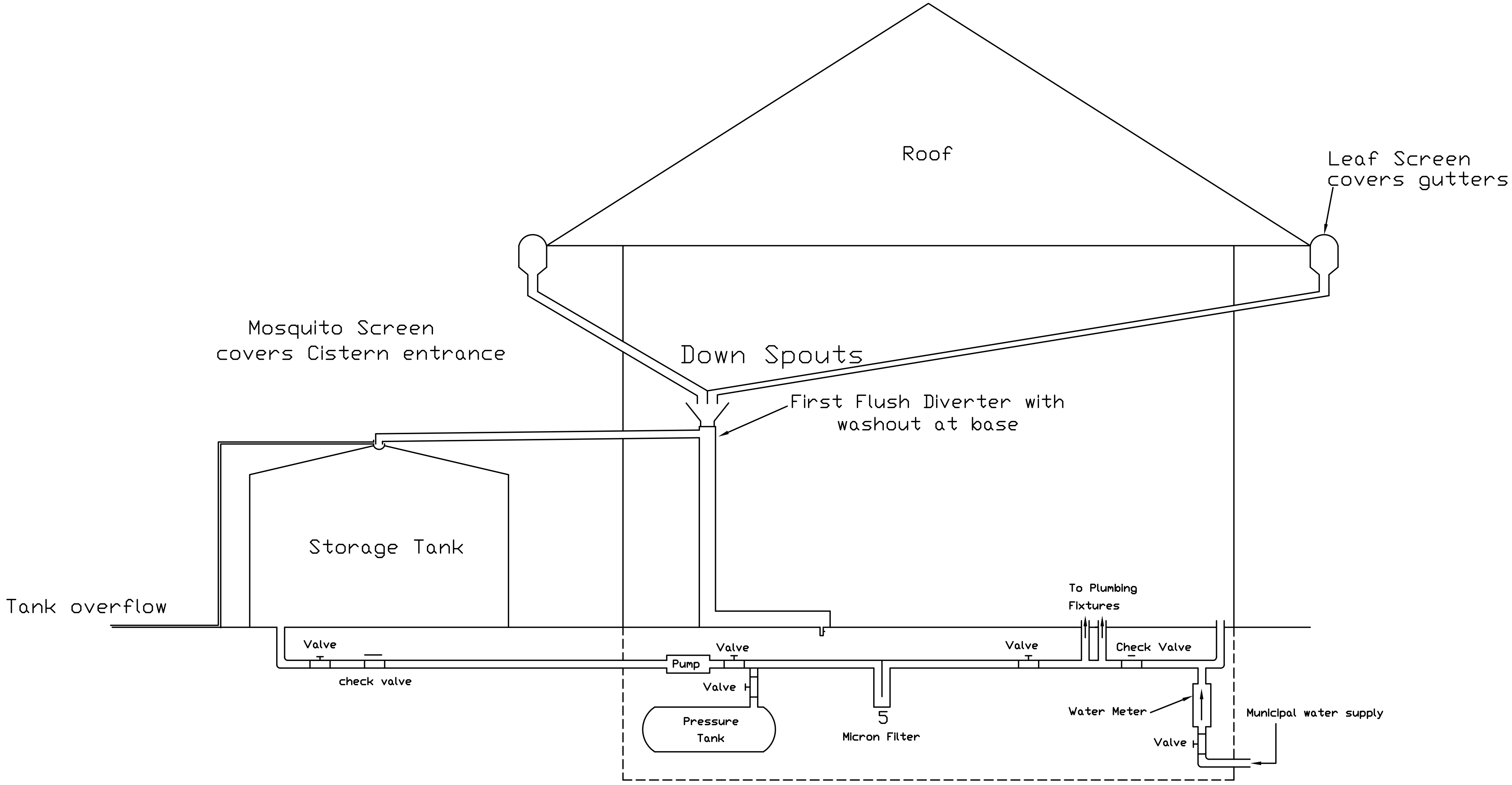
No.	Initial	Revision/Issue	Date

Project Title:
Rainwater Harvesting

Drawing Title:
Basic Gravity Household
Connection Detail with 1 Filter

Date: August 2018
Scale: Not to scale
Project No: DVRP-RWH-18
Drawn By: L. Arnold
Checked By: L. Arnold
Drawing No: RWH-02

Designed By:
L. Arnold



Note : Disinfection is done manually at the storage tank using household bleach

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Notes

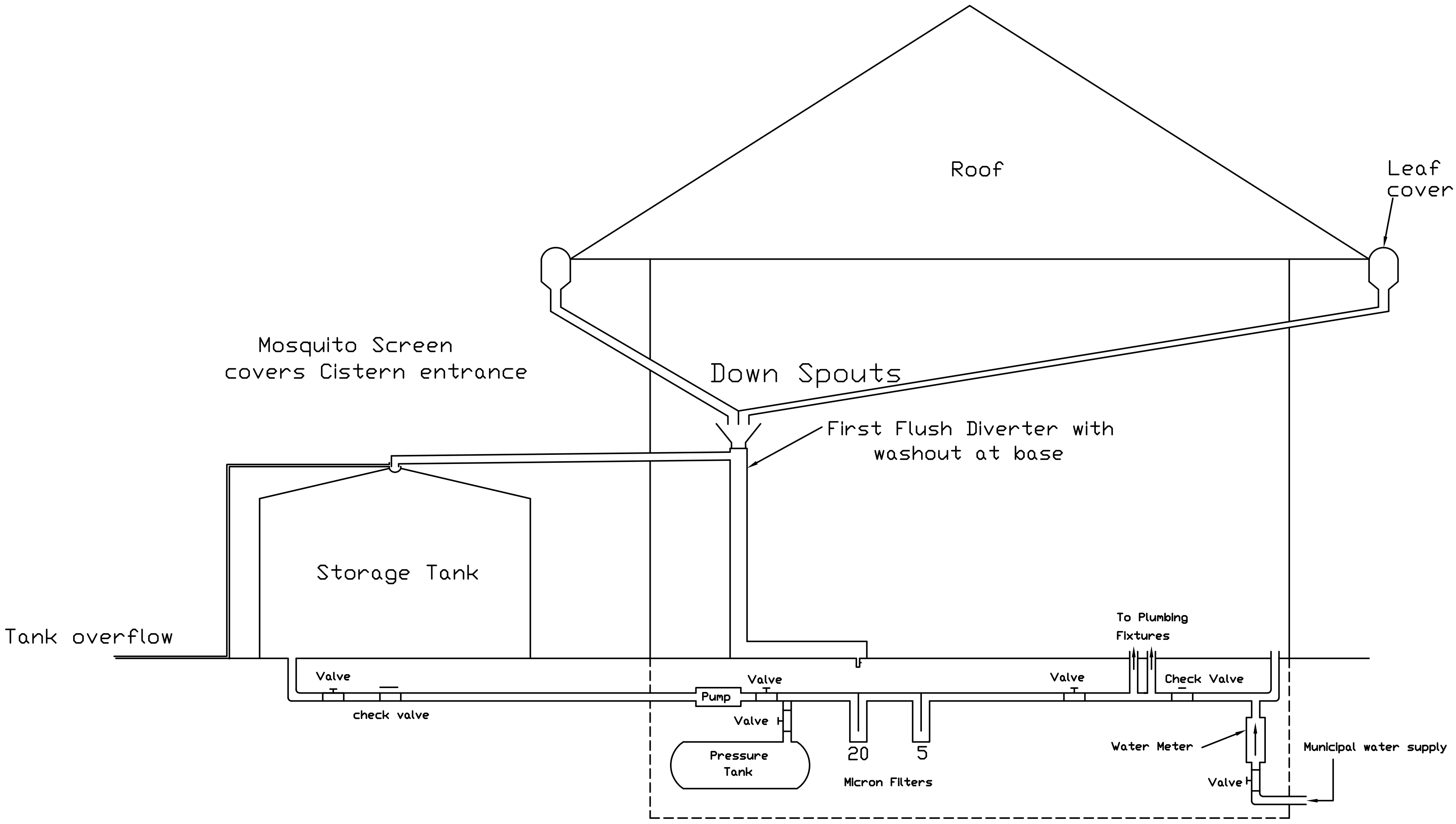
No.	Initial	Revision/Issue	Date

Project Title:
Rainwater Harvesting

Drawing Title:
Basic Household Connection Detail
with 1 Filter (Pumped Option)

Date: August 2018
Scale: Not to scale
Drawn By: L. Arnold
Checked By: L. Arnold
Project No: DVRP-RWH-18
Drawing No: RWH-03

Designed By:
L. Arnold



Note : Disinfection is done manually at the storage tank using household bleach

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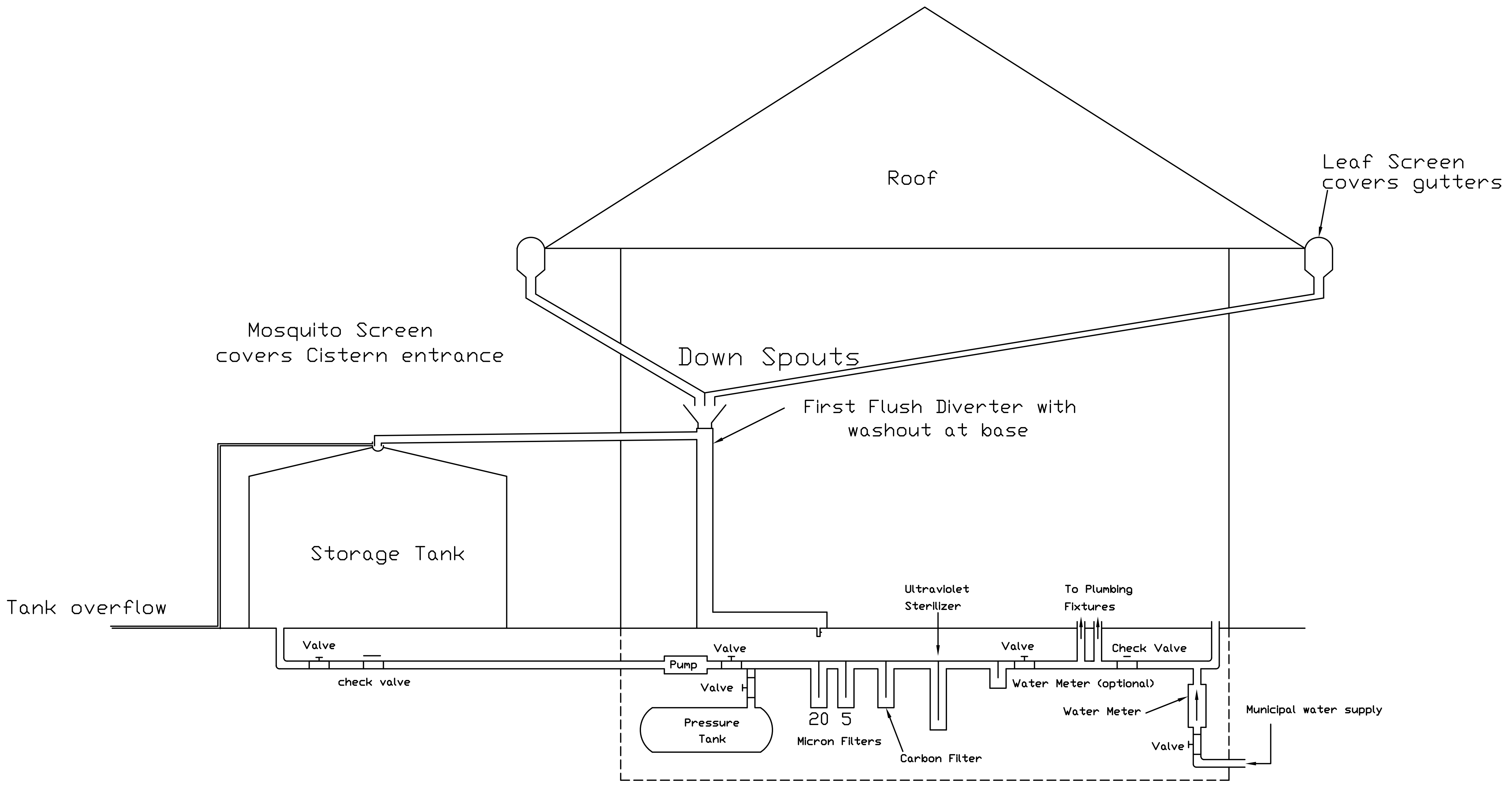
Notes

No.	Initial	Revision/Issue	Date

Project Title:
Rainwater Harvesting

Drawing Title:
Basic Household Connection
Detail with 2 Filters

Date: August 2018
Scale: Not to scale
Project No: DVRP-RWH-18
Drawn By: L. Arnold
Checked By: L. Arnold
Drawing No: RWH-04
Designed By: L. Arnold



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Notes

No.	Initial	Revision/Issue	Date

Project Title:
Rainwater Harvesting

Drawing Title:
Public Facility Connection Detail

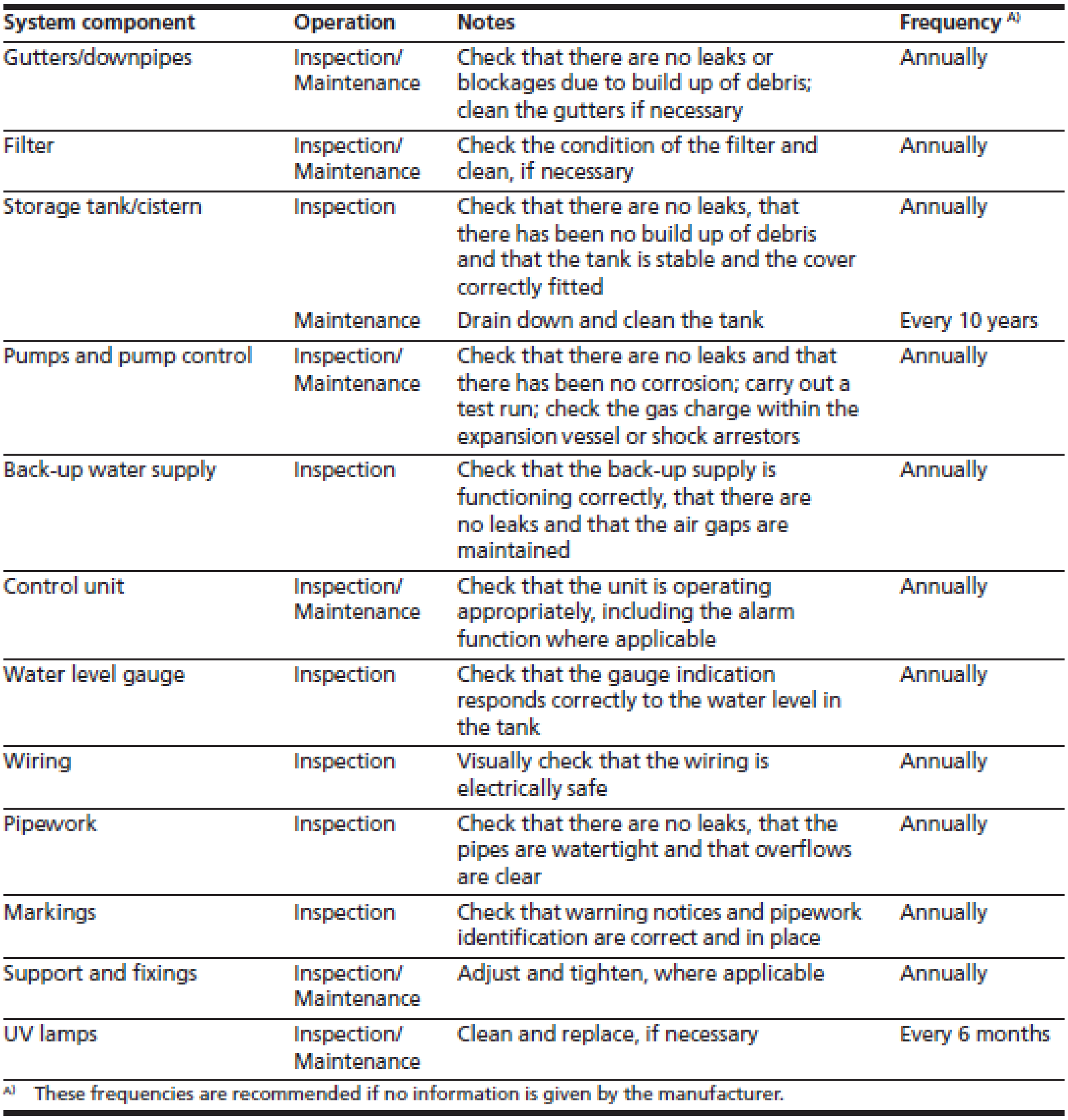
Date: August 2018
Scale: Not to scale
Project No: DVRP-RWH-18
Drawn By: L. Arnold
Checked By: L. Arnold
Drawing No: RWH-05

Designed By:
L. Arnold

APPENDIX I

Maintenance Schedule

Maintenance Schedule



System component	Operation	Notes	Frequency [A)]
Gutters/downpipes	Inspection/ Maintenance	Check that there are no leaks or blockages due to build up of debris; clean the gutters if necessary	Annually
Filter	Inspection/ Maintenance	Check the condition of the filter and clean, if necessary	Annually
Storage tank/cistern	Inspection	Check that there are no leaks, that there has been no build up of debris and that the tank is stable and the cover correctly fitted	Annually
	Maintenance	Drain down and clean the tank	Every 10 years
Pumps and pump control	Inspection/ Maintenance	Check that there are no leaks and that there has been no corrosion; carry out a test run; check the gas charge within the expansion vessel or shock arrestors	Annually
Back-up water supply	Inspection	Check that the back-up supply is functioning correctly, that there are no leaks and that the air gaps are maintained	Annually
Control unit	Inspection/ Maintenance	Check that the unit is operating appropriately, including the alarm function where applicable	Annually
Water level gauge	Inspection	Check that the gauge indication responds correctly to the water level in the tank	Annually
Wiring	Inspection	Visually check that the wiring is electrically safe	Annually
Pipework	Inspection	Check that there are no leaks, that the pipes are watertight and that overflows are clear	Annually
Markings	Inspection	Check that warning notices and pipework identification are correct and in place	Annually
Support and fixings	Inspection/ Maintenance	Adjust and tighten, where applicable	Annually
UV lamps	Inspection/ Maintenance	Clean and replace, if necessary	Every 6 months

[A)] These frequencies are recommended if no information is given by the manufacturer.