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THE WATER PROJECT JAMAICA

Water Adaptation Guidelines

FOR NEW HOUSE CONSTRUCTION & RETROFITTING IN JAMAICA

[FOREWORD]

The Jamaica Developers Association is pleased to have been included in the deliberations for the development of "The Water Project Jamaica – Water Adaptation Guidelines" facilitated by the JN Foundation, the Inter-American Development Bank (IADB) and JN Bank.

This project was designed to address water management issues related to Climate Change – a very real problem for Small Island Development States. These guidelines respond to the need to educate key stakeholders, such as homeowners and developers, on the financial and environmental benefits of including water conservation and recycling systems in their design decisions. Homeowners will benefit from a more consistent supply and lower rates. Developers will find that these design features will appeal to informed consumers.

Historically, Jamaica has suffered from periods of intense drought. These episodes are projected to become more prolonged, with interludes of very heavy rainfall. The storage of sufficient water and its efficient usage are now persistent challenges to water resource management. Rain water harvesting and grey-water recycling are two ways of maximizing the use of limited water resources.

The Jamaica Developers Association thanks JN Foundation, IADB and JN Bank for producing these Water Adaptation Guidelines and urge our membership and other stakeholders to adopt the suggested conservation techniques in their projects.

Jamaica Developers Association

Dayton Wood
Chairman

This document outlines the technical specifications and requirements that guide the construction and retrofitting of homes in Jamaica in order to increase the efficiency of water conservation, while mitigating loss. Such measures are primarily directed at the demand side of water consumption and focus on building the resilience of households against future water crises.

PREFACE

This guide outlines a set of water adaptation technologies and refers to a number of national policies and standards and/or requirements that are relevant and applicable to the design and specification of new house construction and retrofitting across Jamaica. To incorporate water adaptation technologies, Jamaican developers at present have to sift through at least seven (7) different national policies and standards to ascertain pertinent information applicable to the design and retrofitting of family dwellings.

The following guideline aims to simplify this process and assembles all relevant water adaptation information needed for the design and specification of new house construction and retrofitting across Jamaica. It is to be used by technical professionals involved in the design and specification processes (architects, engineers, developers/planners, and other building professionals).

A simplified, comprehensive guideline such as this supports the uptake of water-efficiency measures in the housing sector across Jamaica. Further, it is expected that the incorporation of these guidelines in the design, specification, and retrofitting of family dwellings will enhance Jamaica's climate resilience through increased use of water adaptation technology, contributing to the achievement of goals under the Vision 2030 National Development Plan.

The JN Foundation, as an implementing agency of the IADB-funded project, Financing Water Adaptation in Jamaica's New Urban Housing Sector, contributed to the development of these guidelines in its capacity as project manager and as a key stakeholder in the housing development sector of Jamaica.

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EXECUTIVE SUMMARY

With climate change now at the forefront of developmental concerns, the JN Foundation intends to take a leading position in facilitating the implementation of water stress resilient infrastructure through training and financing. For the most part, Jamaica's housing infrastructure has not been built with water efficiency or conservation in mind, as housing design was not carried out with consumers' usage of water as a critical design criterion. The absence of infrastructural capability for efficiency means that it is becoming increasingly difficult to manage worsening, periodic water shortages. We are already in the early phases of a global water crisis and action must now be taken to avert and adapt to any impending water scarcities. The guiding assumption to the implementation of these technologies in this document is that water supply is kept in accordance with national projections, and thus this document seeks to reduce consumption from the demand management side.

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The introduction of the document provides the background narrative upon which the entire guideline is based. It begins with a look at how the guideline fits within the National Water Sector Policy framework that already exists, along with other national policies. The next two sections - The Jamaican Situation: A Cause for Concern and A Future in Crisis: The Case of South Africa - gives an analysis of the present situation in both Jamaica and South Africa. Given that retrofitting and construction involves design considerations, the aesthetic of water adaptation solutions is where consumer interests meet technical sustainable development. This reminds developers of the use of space/land and addresses concerns homeowners may have about how high-efficiency technology enhances the beauty of their home. Making the instalments visually pleasing, with enough variety in styles, will boost customer buy-in and morale about water conservation within the home.

MANAGEMENT OF WATER RESOURCES

The document covers twelve (12) technologies that enhance the management of water resources within homes, focusing primarily on water efficiency, reducing demand, and increased rainwater catchment. Implementing the outlined measures within the housing sector is the means by which a water crisis can be averted. Each technology is dealt with in Chapter 4: Water Adaptation Technologies. The leading use of water in homes is from bathrooms. Toilets are the highest consumer within the bathroom, followed by showerheads and faucets. We recommend a focus on retrofitting these with more efficient technologies.

Retrofitting bathrooms alone can reduce water consumption in the entire home by at least 50% once sensitisation is done along with the retrofitting. Details about the types of available upgrades recommended for each technology can be found: water-efficient toilets, water-efficient showerheads, water-efficient faucets and low-flow faucet aerators, water-efficient washing machines, water-efficient dishwashers, and leak-detection technology. Mention is made of the consequences of implementing each within the home.

Technologies such as rainwater harvesting systems and greywater recycling systems (recovery and reuse) require implementation mostly from the construction rather than retrofitting perspective. A significant amount of water is used to water lawns and maintain gardens in homes, and technologies such as drip irrigation systems and other water adaptation technologies will reduce demand in this area while improving the aesthetics of the environment. Retrofitting and constructing using these technologies in households is the single most cost-effective move Jamaica can immediately implement to address concerns of how we manage water demand in light of climate change and achieving National Goal 4 of Vision 2030 Jamaica – National Development Plan, which has this focus – 'Jamaica has a healthy natural environment'.

Within the focus on constructing a sustainable Jamaican home for the future, special interest is placed on technologies such as rainwater harvesting systems and greywater recycling systems (recovery and reuse). We cover the basic construction of water catchments and greywater recycling systems that fulfil the demand for an average home, all informed by best practices in plumbing, engineering, and development in the area. The development approach of rainwater harvesting in this document seeks to have both potable and non-potable water as outputs. Thus, the guidelines are aimed at achieving this in homes with no other access to a central potable water-supply system or homes with central access but require the option to offset water usage. However, the most immediately implementable rainwater harvesting system at reasonably low cost is to use rainwater within bathrooms and for laundry purposes, while greywater can be used for irrigation.

IMPROVEMENTS AND RECOMMENDATIONS

This document seeks to address gaps that currently exist between policy and current development practices. Managing the water demand in households from the point of how we construct homes is our method of making policy a reality. Other areas of improvement are listed in the recommendations. One recommendation is for there to be more private-public partnerships where the private sector picks up the slack in areas that government has not yet addressed or cannot address directly.

Our second recommendation is to develop a Jamaican Residential Green Building Code that takes into consideration written policies on climate change, water-use efficiency, energy efficiency and conservation, renewable energy use, and environmental design.

Third, there is urgent need for the finalisation of a national standard for potable water. Finally, it should be mandated that leak-detection systems be included within designs for new hous- ing scheme developments.

In the final analysis of how we go about adapting to water shortages brought on by a changing climate, the implementation of the recommended technologies will go a far way in enabling climate resilience.

VISION 2030

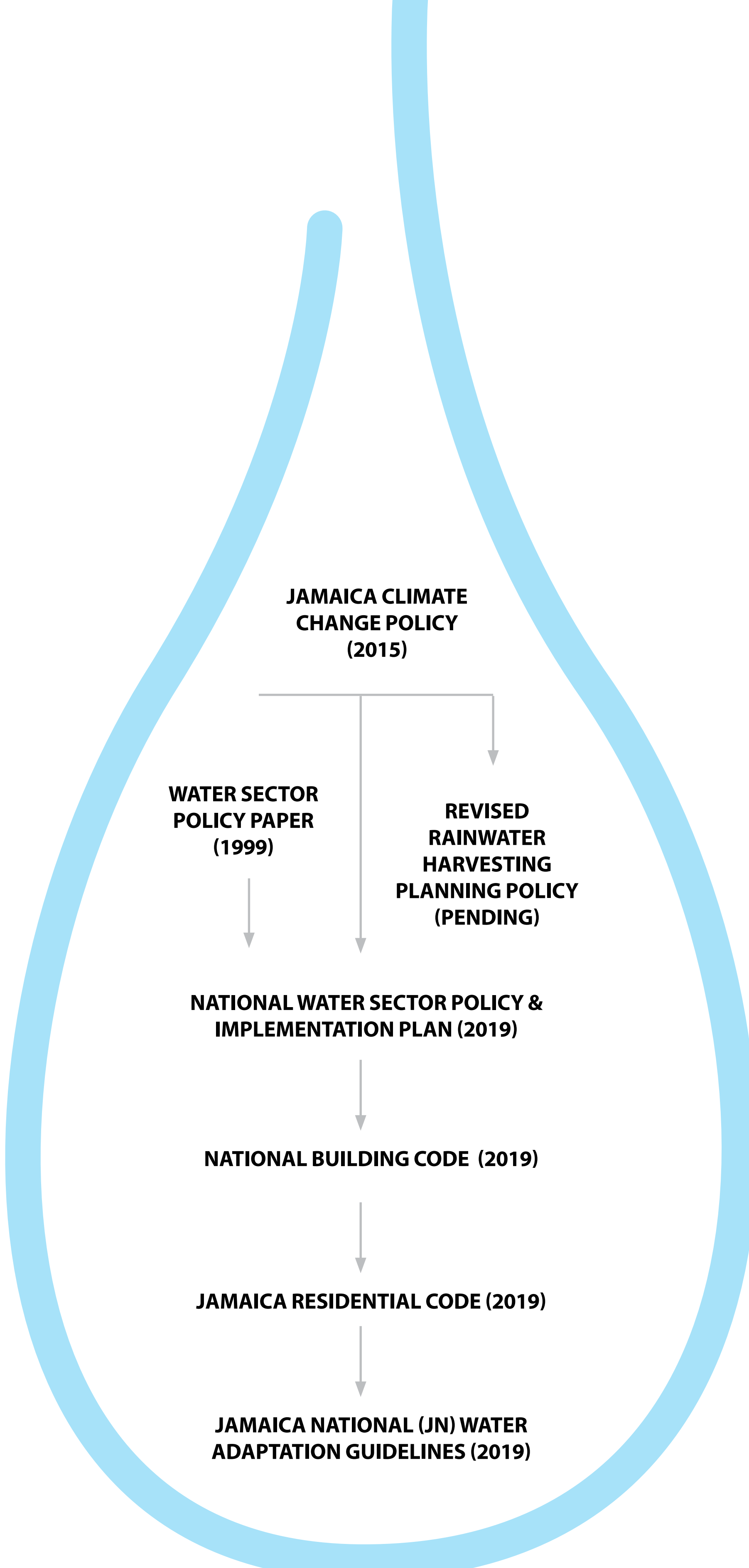


Figure 1: Details how this Guideline Document fits within Jamaica's Policy Structure

[2]

INTRODUCTION

2.1 Legislative, Regulatory and Policy Frameworks in Jamaica

With evidence that climate change is taking place at an accelerated rate and water being a very climate-sensitive resource, Jamaica has put in place a policy and legislative framework aimed at resilience in the face of the coming climate crisis. To this end, the country has committed to a vision of enhancing resilience and our capacity to adapt while mitigating causes in a coordinated, effective and sustainable manner *(Government of Jamaica, 2015)*. One of the government's policy objectives is to mainstream climate-change objectives into all types and levels of development. The **JN Water Project Jamaica** intends to do exactly this by injecting into the housing sector design and retrofitting specifications to manage water consumption. We will do this by training relevant stakeholders within the housing development sector on how to design and build with an awareness of a future water crisis in mind. This guideline draws from different areas focused on sustainable development for the country and in its own way acts as a means of streamlining policy into one, single implementable project.

Another objective by the Government (GoJ) is to make climate financing available for adaptation and mitigation initiatives. As a financial institution, the JN Group sees it as a national duty to provide financing for developers to build homes that efficiently manage water consumption. While the supply of water to the public at large is mainly managed by arms of the government, it is the habituated use of this resource that has a larger impact on our environment. After all, the accelerated rate of climate change is mainly caused by human activity. As such, we aim to instil change from the consumption side by providing homeowners with the necessary infrastructural means to manage their water-consumption habits.

The 2030 Agenda for Sustainable Development officially began its operation on January 1, 2016 and was designed to solve some pressing worldwide challenges based on seventeen (17) stated sustainable development goals (SDGs). Goal 6 of the SDGs seeks to "ensure availability and sustainable management of water and sanitation for all." This encapsulates the global agenda that underpins this project's funding from the Inter-American Development Bank (IDB). Water resources are seen as essential to sustainable development, as drinking water, hygiene, and sanitation directly affect development in other areas such as education, health, and poverty reduction. Central to water-resource management is the concept of 'water stress'. This is the ratio of total freshwater withdrawn by all major sectors to the total renewable freshwater resources in a particular country or region.

Within this international context, in 2009, Jamaica sought to promulgate its agenda for sustainable development with the Vision 2030 National Development Plan. The Development Plan speaks to the need to provide adequate potable water and sewerage services (Vision 2030, NDP). Goal 4 aims for Jamaica to have a healthy natural environment. It outlines three outcomes of this pursuit: sustainable management of natural resources, risk reduction, and adaptation to climate change, and sustainable urban and rural development. It is within these considerations and aims that this guideline fills the gaps on the road to achieving the outcomes mentioned.

ADAPTATION AND MITIGATION MEASURES

Beginning with Jamaica's Climate Change Policy, there are two initiatives that are relevant to the government's adaptation and mitigation measures, which this guideline aligns with. These are the Special Initiative for Water Resources Management and Special Initiative for Land Use Planning. The implementation of water-conservation technologies in house construction and retrofitting directly aligns with government initiatives to manage water resources in combating climate change. Another aspect pertains to aesthetic considerations and land utilisation, while also taking into account rainfall patterns, geomorphology, and size. These factors play a role in determining catchment sites in house construction. This guideline aligns with the government's initiative for land use in tackling climate change.

As it relates to water-resource management, this document draws from Jamaica's Water Sector Policy (1999) framework, which mentioned the implementation of a demand management strategy as an objective. This was further detailed in the 2009-2030 Water Sector Plan, which incorporated objectives of the Climate Change Policy. The National Water Sector Policy and Implementation Plan highlighted the need to implement public education programmes, provide incentives to encourage homeowners, businesses, institutions, and private service providers to invest in water-efficient technologies, and encourage water reuse and recycling. These are all currently being addressed by this water project in active implementation.

By providing financing to housing developers with training in implementing water adaptation technologies, we are creating opportunities for the emergence of a new market centred on sustainability, thereby making available necessary infrastructure for future adaptability. Guided by the Jamaica residential building codes that specifically outline the construction of single- and two-storey residential buildings, this guideline is intended to act as a road map to how Jamaica should construct housing on the premise of water being a critical resource. This is a move in the direction of adapting to the new normal that is entirely different from the development perspective of the early 20th century. Developers at that time, especially those in the housing sector, operated under the judgement that water was abundant and inexhaustible. This perspective must change in order to meet the challenges posed by climate change and, as such, measures should be taken within the housing market to enable consumers to better manage their water consumption. By placing an emphasis on the demand side of managing water, it enables the country to be more resilient to the coming crisis.

2.2 The Jamaican Situation: A Cause for Concern

At the beginning of the 21st century, Jamaica reviewed the water sector and found that there was deterioration and malfunction of municipal supply, rapidly increasing water demand in water-deficient areas, and deforestation of watersheds. Along with insufficient storage capacity for the the dry season, concerns about the nation's vulnerability to climate variability was at the forefront. To address these concerns, the National Water Sector Policy (1999) was developed with an aim of universal access to potable water by 2030. This policy forms the actionable foundations for Goal 4 of Vision 2030, which is to see Jamaica having a healthy environment. This is to be achieved through sustainable use and management of environment (land) and natural resources (water). Sustainable development of our urban and rural areas to make them adaptable to climate change encompasses the outcomes targeted by 2030.

Jamaica is already experiencing the effects of climate change with prolonged periods without rain. In recent decades, this has caused the National Water Commission to do scheduled regulation of water supply for some communities, especially those within the Kingston Metropolitan Area (KMA). With the country usually receiving two peaks in rainfall volume annually, there is now a situation where the secondary rain period, in May-June, occasionally falls below expectations. This results in prolonged dry periods. As a result, Jamaica experienced one of the longest dry period in recent history from December 2018 to April 2019 (National Water Commission, 2019). The Kingston Metropolitan Area is particularly at risk, as not only does this geographical region traditionally receive the least amount of rainfall, the city also relies significantly on surface water (reservoirs). In 2019, just before the start of the second rainy season, the two major water sources for Kingston, the Mona Reservoir and the Hermitage Dam experienced storage levels of around 25% and 40%, respectively (National Water Commission, 2019). By the start of the second rainy season in September, there were slight increases to a recovery of around 70% for Mona and 80% for Hermitage in October 2019. The expected dry season should begin again in December, and with such a slow pace of recovery, given a number of years of this cycle repeating, the metropolis will be facing severe water shortages.

THREAT OF SIGNIFICANT WATER SHORTAGE

With Greater Kingston having the largest number of households in Jamaica, with almost half of the island's population, the causes for concern are numerous. Not only is there a threat of significant water shortage in the future, but also concern about the depletion of the watersheds that supply the city. Three major watersheds supplying the Kingston Metropolitan Area are the Yallahs River, Hope River, and Rio Cobre. These three watersheds provide less than 50% of the supply for the metropolis. All three have suffered severe degradation, with around 50% of the areas prone to landslides and 65% to erosion *(Angus, 2015)*. The main cause of this has been deforestation, leading to poorer water retention to refill underground aquifers.

There are already instances of beach erosion caused by climate change along Jamaican shores. The area with the highest rate of urbanisation in Jamaica is St Catherine. It is rapidly growing into what appears to be a third city, with Portmore being one of the flagship urban centres. Already, beach erosion is evident along the Hellshire Beach in the area. With an increasing number of housing developments, indicators such as these should guide construction practices to mitigate flooding. Coastal intrusion not only warrants flooding to be the sole cause for concern, but water shortages can also result from the intrusion of salt water in the groundwater supply. Globally, coastal urban areas are the first to be significantly impacted in ongoing climate change. Jamaica should take note in this regard, since most of the island's development is along the coast.

Undoubtedly, the primary cause for concern is water stress. One of the most severe droughts for Jamaica was in the summer of 2015. This was not simply a localized weather event, as it also affected the wider Caribbean, causing the most severe shortage of water than ever before. As such, measures must be put in place to manage demand in a world where the realities of a limited supply are a looming possibility now more than ever.

It is for these eight reasons the Ministry of Water and Housing in 2004 had outlined strategies, including household taps and catchment tanks. The Water Project being undertaken by the JN Foundation brings these long-thought-of strategies to the fore-front of development within the housing sector. With current economic growth projections and the increase in production within the construction industry, there is no better time than now for the implementation of water adaptation technologies within homes.

2.3 A Future in Crisis: The Case of South Africa

Fresh water is a necessary resource, and because of changes to the global climate, water resources are under threat all over the world. While many people in the world already lack adequate access to fresh water, this problem will get worse given the extreme climatic events that come with global climate change. Indeed, it did get worse for South Africa in 2015 with the beginning of what eventually turned into a three-year drought. Severe water-shortage conditions in South Africa, and how they were handled, stand as a lesson on how countries will have to manage their own future water crises.

Declining water resources in 2015 saw some reprieve by 2016 for parts of the interior of South Africa. Those regions had got enough rain to cause flooding and abated the severe drought conditions. The Western Cape region, however, was yet to experience the worst of the drought. By 2017, the country and, especially, the Western Cape were experiencing the lowest recorded rainfall since records began. The government at this point began to encourage greywater recycling and water reuse. By October 2017, Cape Town projected to have five months of water supply left, and by January 2018, municipal water supply was cut in anticipation of Day Zero when the water level of the major dams supplying the city reached 13.5%. Dam storage levels were monitored and fortnightly data used to project Day Zero's arrival. Implementing a water-rationing system of 25 litres per day per person with 149 water-collection points across the city, Cape Town was able to hold off Day Zero. Residential and agricultural use of water declined significantly. This caused Day Zero to be rolled in stages to the point where, by June 2018, Day Zero was postponed indefinitely. The 2018 season produced good volumes, so much so that by September, dam levels were close to 70 per cent. To fully understand how South Africa and, especially an urban area such as Cape Town, survived such a severe drought event, we must first look at the context of South Africa.

South Africa is a semi-arid country because of low annual rainfall per annum (approximately 464mm). This means the water stress for the country is high, with rainfall patterns that vary widely along with a high evaporation rate. Therefore, South African people are in some way conditionally adaptable to water shortages. The country relies mostly on surface water for most of its supply with around 320 dams. Some rural areas are supplied by underground aquifers, of which there are few with large enough freshwater reserves (Adewumi, Ilemobade, & Zyl, 2010). The underground aquifers in the country have high salinity, especially in coastal regions.

WATER MANAGEMENT SYSTEMS

South Africa's water system is divided into 19 water management areas. Most of South Africa's water supply comes from surface sources with around half of the water-management areas experiencing water deficit (Adewumi, Ilemobade, & Zyl, 2010). Factors such as climate change and economic growth are severely affecting supply reserves. With the aridity of the region, increasing water use from urbanisation and the pollution of surface and groundwater resources, municipalities have been challenged to explore alternative sources. The Department of Water Affairs and Forestry, in anticipation of climatic change, implemented special attention catchment-monitoring programmes and wastewater reuse programmes.

The catchment-monitoring programme was important given that not everyone involved in water management are experts in all environmental compartments. By integrating measurements for groundwater, surface water, unsaturated zone, and the atmosphere into their catchment-monitoring programme, linkages were made apparent across areas of expertise such as geology, climate, soil, and land use. With a toolbox that is accessible to catchment managers and government departments, private sector, and infrastructural developers can make decisions based on a more data-driven and informed manner with regard to water management and sustainability.

The wastewater reuse programme entails the collection of wastewater, which is processed and used for non-drinking requirements within the same building, or home that generated the wastewater. Wastewater may be collected at a central location from domestic and non-domestic sources within an urban/agricultural area, processed and used elsewhere. Wastewater reuse for non-drinking water requirements has been, for many years, a promising option for supplementing municipal water supply despite the limited implementation. South Africa currently implements some of these efforts through public-private partnerships.

Within the urban areas, there are water reuse systems such as dual water reticulation. This is a system consisting of separate pipes that supply drinking and treated wastewater for separate uses. For instance, wastewater from washing machines is channelled via pipes to irrigate lawns above the surface. While, on the other hand, wastewater from the kitchen is channelled – via rock-filled trenches with fat traps, a mulch layer, sawdust and a removable plastic basket – to irrigate lawns below surface.

Communities designed with water reuse systems such as this, are better able to respond to water-supply shortages and rely less on chemical fertilisers. The added benefit being the reduction of underground water contamination by fertilisers. The Lynedoch Eco-Village, in the Western Cape Province, had this very idea in mind when it was founded in 1999. The interesting thing about South Africa in regard to their preparedness and response to the drought of 2015 was that systems were in place decades before that enabled them to tackle the severe water shortage crisis. Since the 1990s, Cape Town insisted on increased efficiency of the water system by reducing leaks and encouraging a community development focus on sustainability and water conservation. As a result, despite the growth in urbanisation, the city's demand for water has actually been steady. Communities, such as Lynedoch Eco-Village, was a pioneering development

Figure 2 Lynedoch Eco-Village Layout Plan. Retrieved from: http://www.liane-network.org/wp-content/uploads/2015/08/Lynedoch-Map.png

project with an ecological design focus, where not only financial considerations were taken into account, but also the ecological footprint. On-site vermiculture-based waste treatment systems were integrated to treat all liquid and organic waste for reuse.

Despite these innovative changes, the situation in South-Africa was still lacking, with the Institute for Security Studies (ISS) reporting in 2014 that South Africa was overexploiting their water resources. The 2014 report pointed out that around a quarter of the wastewater treatment facilities were in critical condition, with another quarter at high risk *(Hedden & Cilliers, 2014)*. Given these challenges, it is important to realise that it could have been far worse, and Cape Town narrowly averted a disaster. It is left up to us now to realise that conservation is the big game for the near future, with South Africa being a model of how to go about this in a more efficient manner with no more narrow escapes.

Cape Town is far from the only city to come to the brink of losing its supplies of drinking water. It has however been the most transparent and politically accountable in how it dealt with the crisis. Some key points to take away from South Africa's handling of the crisis:

Facilitating grassroots behavioural change

From the standpoint of conservation, toilets, clothes washers, leaks, and showers are the most obvious places to begin. In rolling out the Day Zero campaign, people were told to save water from showers in a pail for reuse in cleaning other things. There were billboards instructing people that showers should be two minutes long. Not only were these kinds of messages pervasive throughout the city but there was a culture shift. It makes sense that these strategies worked since psychological and behavioural variables account for a significant portion of household water-use practices *(Fielding, Russell, Spinks, & Mankad, 2012)*. By clearly indicating a catastrophic event to avoid, that being Day Zero, it acted as a tagline for a moral-suasion campaign instilling good conservation habits *(Pérez-Urdialesa & García-Valiñas, 2016*).

Ecological infrastructural innovation

The infrastructural measures set in place from the 1990s that focused on conservation and water recycling instead of infrastructure to increase water supply played an important part in averting the crisis. Not only did it condition the people to be conservative, they also had the means available to them to launch a strict, conservative effort such as shutting off the municipal water supply totally. Their water-monitoring programmes enabled them to make predictions about the crisis with a large amount of confidence. This gave adequate time to put measures in place and predict water supply five to six months in the future. With some communities already having wastewater treatment facilities, they reduced the national strain on the overall system with the emergency conservation efforts. Experience and insight from the Sustainability Institutes, from communities such as Lynedoch Eco-Village, became invaluable to efforts, with their management of the crisis acting as proof of theory.

Community Focus

Water conservation efforts for reduced shower times and water rationing could have been left up to individuals. This could be done while implementing the behaviour-change campaign and not rationing the municipal supply from source. However, not only would the variables increase for potential water loss, but also a community-focused approach, with the allocation of the 149 sites, made management easier. A focus on municipal management and community spirit not only made it apparent that everyone was in the crisis together, but efforts to avert it were made obvious to all and no single person felt the pressures of unbearable responsibility with their individual conservation efforts.

One of the main challenges humans face is accepting change when it is not predictable. Inability to do this means that one does not have a long-term strategy capable of forecasting and preparing. In the case of South Africa, they had an adaptive response capable of managing a 2015 drought that was unpredictable.

The winter of 2014 had dams overflowing and the forecast for the 2015 drought did not project it lasting for more than the year. However, with the Western Cape region being hit the hardest and the drought being protracted, the management experts in South Africa were able to respond. This is credited to the incorporation of sustainable development as a core to management education in the country. In a similar manner, we aim to pioneer real-estate development in Jamaica with a sustainable focus capable of responding to future water crises in Jamaica.

[3]

THE IMPACTS OF CLIMATE CHANGE ON THE HOUSING SECTOR IN JAMAICA

438,014

(50%) of households in Jamaica have water piped into their homes

145,269

(16%) of households in Jamaica have water piped into their yard

62,161

(7%) of households in Jamaica have access to standpipes

19,348

(2%) households use catchments to obtain water

The total number of households in Jamaica stands at around 881,089, with 477,201 households (54%) in urban areas. The port city of Kingston & St. Andrew contains around 198,076 (24%) of these households. There is an increased trend of urbanisation in Jamaica accompanied by a boom in the housing sector. Increases are particularly concentrated between Kingston & St. Andrew and St. Catherine. One of the main concerns for such developments as it relates to climate change is the availability of fresh water. This is especially so since Kingston & St. Andrew is the most urbanised place on the island, while also being the place that receives the least amount of rainfall. It is thus that one of the most important impacts of climate change to consider is the prolonged periods of drought and rain, a situation that inevitably will lead to further water shortages and flooding.

ACCESS TO WATER

As it currently stands, 438,014 (50%) households in Jamaica have water piped into their homes, 145,269 (16%) into their yard, and 62,161 (7%) with access to standpipes. Another 19,348 (2%) households use catchments to obtain water. This yields around 664,792 (75%) with direct access to fresh water and a significant number of households with needs unmet. This reflects a more general problem of poor housing conditions. This will be expected to worsen with the effects of water shortages that climate change will have on the population.

The impact of flooding on the housing sector is possibly a far more serious issue than water shortages. This is mainly because around 91.3% of the total population live within 25km of the coastline. Approximately 24% of the population lives as close as 5km from the Coastline. However, it is the informal settlements that will be most severely affected. Already, within Kingston & St. Andrew, more than half of the informal (squatter) settlements are within 100m of a waterway susceptible to flooding.

INFORMAL SETTLEMENT & DEFORESTATION

Let us make clear the kind of housing conditions that flooding will affect the most. There are more than 750 informal settlements in Jamaica, housing around 600,000 (20%) of the population. Most of these settlements are located within urban areas, namely Kingston & St. Andrew. In fact, uncontrolled housing developments have been a major issue for coastal areas and water management, as noted by the Natural Resources Conservation Authority. Large-scale removal of trees for housing developments and squatter settlements, among other things, has created the problem of deforestation. That not only makes the low-lying areas more prone to flooding but exacerbates water shortages by reducing rainfall.

Ultimately, the two most significant impacts of climate change on Jamaica's urban housing sector is that of water shortages caused by a longer dry season and flooding linked to the concentration of more rain in a shorter wet season. The ensuing change in the climate means that Jamaica's resilience will depend on how adequately we are able to conserve water in the dry seasons and harvest water in the rainy seasons.

600,000 people

There are over 750 informal settlements in Jamaica, housing around 600,000 (20%) of the population.

[4]

THE AESTHETICS OF WATER ADAPTATION SOLUTIONS

Greywater is the low-polluted wastewater from bathtubs, showers, hand-washing basins and sometimes washing machines, and usually excludes wastewater from the kitchen and the toilet flushing system. Greywater typically has colour along with suspended solids. In the implementation of solutions aimed at greywater recycling, aesthetics must be taken into consideration. Treated water must not be a source of odours, nuisance to consumers, and it should be nearly free from suspended solids and colours.

In addition to the aesthetic concerns related to water quality, the systems employed for rainwater harvesting must be evaluated not only for their efficiency, but they must also not devalue homes with their appearance. As such, aesthetic principles must be taken into account in the design phase of these rainwater-harvesting systems. Together, both water recycling and water harvesting highlight how aesthetics becomes a factor in the implementation of these systems. Aesthetics, as it relates to the other technologies, come into play with regard to their standard designs and how these match with other fixtures within the home.

Since toilets, showerheads, faucets, aerators, washing machines, and dishwashers do not have as imposing a presence in the home, as a rainwater harvesting system would because of size, the design considerations pertain more with how they match with other fixtures and themselves. As such, the aesthetic appeal of these household utilities provides some cultural services to the household and surrounding landscape. On a whole, the housing sector, in relation to climate change, must pay attention to the landscape of the areas being developed. As such, the National Works Agency has guidelines for preparing designs and reports for drainage systems in development applications.

These guidelines call for the inclusion of one's design philosophy and of any watershed influencing the development. These considerations are made with the utility of the land in mind, which can be classified into three categories:

PROVISIONING SERVICES:
Land used for supplying fresh water (watersheds), food cultivation and housing.

REGULATING SERVICES:
Land used for flood control, drainage and water purification.

CULTURAL SERVICES:
Land used for aesthetic and recreational purposes.

Aesthetic considerations when designing and implementing water adaptation solutions, therefore, serve a functional role within the housing sector by adding value in terms of quality, appearance, and cultural significance.

[5]

WATER ADAPTATION TECHNOLOGIES

5.1 Introduction

We are currently facing a water crisis. It is not just local but also global. Water shortages are already being experienced in other countries like Mexico, Argentina, South Africa, Qatar, Iran, India and Jordan, to name a few. These countries are listed by the World Resources Institute as having high water-stress levels of 40-80% and, in some cases, even higher. Professor Madison Powers' website, FEW Resources, estimates that by 2020, 1.8 billion people will experience absolute water scarcity, meaning there will be little to no water resources to live off. The UN currently estimates that around 700 million people worldwide are experiencing absolute water scarcity.

Overall, climate change models predict that by the end of this century, a significantly higher number of people will be exposed to both floods and droughts, according to the Intergovernmental Panel on Climate Change. Availability of clean water in adequate supply for people and nature is under threat by climate change.

This clear and present danger threatens the prolonged existence of the modern industrial society as we know it. Water, as a resource, enables agricultural processing and food cultivation, power generation, household use, and industrial production. With most of the water supply coming from watersheds and produced by rainfall in a continuous cycle, climate change has upset this delicate balance, leading to watershed depletion. This, in turn, leads to water shortages, as can be seen in the case of Kingston. Kingston gets water from a watershed that, in recent decades, has had to be rehabilitated.

Maintaining the balance in the water cycle does not just ensure a continuous flow of water to power our cities and run our industries, but it also facilitates essential services that preserve the ecosystem; services such as water purification, flood mitigation, wildlife habitats, and nutrient cycling. With systems of water purification compromised, exacerbated by pollution and degradation of watersheds, the availability of renewable surface and groundwater resources will decrease over the decades to come.

Climate change is affecting the water cycle on all scales. Changes in rainfall patterns and rising temperatures associated with climate change mean also that there will be more intense rain during the wet seasons. Since rises in temperatures mean that the atmosphere can hold an increasing amount of moisture, the rains do not fall as frequently, but when they do, there will be a lot. This results in increased chances of flooding. Coupled with sea level rise, these intense rains will exacerbate dangers of tidal flooding.

Altogether, climate change's immediate challenge to the housing sector is twofold: a situation wherein there is too little water and another wherein there is too much water. In addressing those problems, solutions fall under two main categories.

i) Water Efficiency and Demand Management

ii) Rainwater Management

Water-efficiency and demand-management measures help reduce inefficient use and waste of freshwater through improved technologies and better oversight of water use. Adaptation responses in this form often employ relatively low-cost technologies. Successful implementation, however, requires a high level of engagement from stakeholders, including the public. Awareness raising and education often play an important role in successful implementation. Directly relating to the use of water-conservation technologies at the level of the household, research has found that information tools are key drivers of water-efficient technologies and habits. Whereas water-efficient technologies can be a significant source of conservation in households, poor water-saving habits could lower the savings *(Pérez-Urdialesa & García-Valiñas, 2016)*. Education, awareness, or moral-suasion campaigns have been found to lead and to spread efficient technologies and instil good conservation habits.

Rainwater management mitigate against flood damages and increase water storage capacity for later use in times of water shortages. Adaptation responses in this form are often on the higher price spectrum when compared to water-efficiency technologies.

Education, awareness or moral-suasion campaigns have been found to lead and to spread efficient technologies and instil good conservation habits.

5.2 Water efficient toilets

Toilet flushing is thus the single highest consumer of water in the average Jamaican home with the bath and shower coming in a close second at 32%.

According to the National Water Commission (NWC), 70-80% of water use in the average household is from the bathroom. More specifically, 40% of water use in the home is from flushing toilets. Toilet flushing is thus the single highest consumer of water in the average Jamaican home with the bath and shower coming in a close second at 32%. One of the simplest techniques possible for a more efficient use of water when flushing toilets is to directly reuse household wastewater for flushing.

The installation of internal water-recycling systems that directly leads to the toilet supply line is a low-cost first step. A next step would be to retrofit inefficient toilets with more water-efficient ones like the dual-flush systems. An old-style single-flush toilet could use up to 12 litres of water per flush, while a standard dual flush toilet uses just a quarter of this on a half-flush. The dual flush toilets save roughly around 20 per cent of the water of conventional single-flush toilets that are widely used in Jamaican households. A study of 30 homes in Tampa, Florida, that retrofitted inefficient toilets, clothes washers, showerheads and faucets showed a decrease in per-capita water use of 49.7%, with the main savings coming from toilets *(Mayer, et al. 2004, 211)*.

Interestingly, countries with a prevalence of dual flush toilets, such as France and Canada, report water usages of 20% and 29%, respectively, in homes. That is almost half the number used in Jamaican homes. In Australia, water use in toilets account for around 15% of water in the home *(Millock and Nauges 2010, 540)*.

Given the sheer volume of water that home toilets have on the consumption habits in Jamaica, the promotion and installation of low-flow or dual-flush toilets in homes could be the single most cost-effective move that can be immediately made within the housing sector, more so if complemented with installation in public restrooms. The evidence for the benefits of such a move is compelling when one examines that 61% of French residents report owning low-flow or dual-flush toilets, 40% of Canadian residents, and in Australia, with the least reported use of flushing water mentioned, 75% reported to having low-flow or dual-flush toilets *(Millock and Nauges 2010, 550)*.

However, it must be noted that in studying the habits in the Organisation for Economic Cooperation and Development (OECD) countries, it was found, that the older the dwelling, the less likely it was for water-efficient technologies in general to be adopted. This was contrary to the common intuition. On the other hand, a slight preference was found specifically for the use of low volume or dual flush toilets, and water tanks to be adopted the older the dwelling. These findings guide us in suggesting that expectations should be measured as it pertains to a mass movement in retrofitting old homes with low-volume or dual-flush toilets. Attempts at encouraging behaviour in this direction should be bolstered and supported by awareness and moral suasion campaigns to instil the habit.

Otherwise, considerable focus should be given to encouraging the use of low-volume or dual-flush toilets in new housing developments as much as possible. Replacement of older toilets with low-volume or dual-flush toilets not only saves water during each use but also lessens water loss because of reduction of leaks *(Leea, Tansela and Balbinb, 2011)*. A four- year study looking at the efficiency of the use of low-volume or dual-flush toilets, efficient showerheads, and washing machines found that out of the three different technologies, low-volume or dual-flush toilets had the lowest water demand. Significant savings up to a 15% reduction in water demand were found three years after retrofitting, with little to no savings found in the first year *(Leea, Tansela and Balbinb, 2011)*. This highlights that the installation of efficient toilets in homes is a long-term solution.

Figure 3: High Efficiency Toilets and Water Use. Retrieved from: https://www.dfcbelize.org/energy-efficiency-technologies/

5.2.1 Jamaican Design Considerations

I. WATER EFFICIENCY REQUIREMENTS:

To be deemed 'water-efficient', the effective flush volume of a toilet shall not exceed 1.28 gallons (4.8 litres). The effective flush volume for dual-flush toilets is calculated by averaging two reduced flushes and one full flush.

II. PERFORMANCE AND OTHER REQUIREMENTS:

Toilets shall pass flush performance criteria based on the waste extraction test protocol in ASME A112.19.2/CSA B45.1 Ceramic Plumbing Fixtures (i.e., flush toilet paper and 350g of miso paste)

- Toilets shall conform to other applicable requirements in ASME A112.19.2/CSA B45.1 and ASME A112.19.14 six-litre water closets equipped with a Dual Flushing device (for dual flush).
- Products shall be marked with the flush volume, according to ASME A112.19.2/CSA B45.1.

5.2.2 Installation

Proper installation is of particular importance for high-efficiency toilets. Licensed plumbers who guarantee their work should do correct installation of fixtures. A licensed plumber is also more likely to follow the manufacturer's instructions, which is also very important. The proper flow cycle for high-efficiency toilets is shorter – usually about 45 seconds - than previous models.

New mounting bolts of the proper length should be used when installing a water-conserving toilet to replace an old one. Also, ensure the old wax seal is completely removed before installing the new one. Check and clear drain lines while accessibility is open.

5.2.3 Use & Maintenance

An important piece of advice still is: "Don't use your toilet as a trash bin." If non-flushable items such as paper towels are sent down the fixture, high-efficiency toilets will not perform well. There has always been a need for plungers and plumbing 'snakes', and their use should be considered first when the toilet overflows or does not refill completely. Since flapper valves require replacement about every five years, proper selection of replacement valves is a key maintenance consideration.

Numerous studies show that to ensure continued performance of water-efficient toilets, proper flapper valve model selection is essential. Of the physically compatible replacement flapper valves, half the models left a toilet with less than 1.28 gpf – and the resulting incomplete flush had insufficient water to do the job the toilet was designed to do. Since most hardware stores can stock only a few brands, there is no guarantee of compatibility. Industry standards groups are working to ensure that aftermarket flappers will perform properly.

Getting the right replacement flapper value is worth the effort. A key problem affecting 1.28 gpf toilets is a result of the use of chemical in-tank toilet cleaners. Toilet manufacturers in the United States recommend against the use of chemical in-tank toilet cleaners, as those agents degrade the works within the toilet. Even with current toilets that include chemical-resistant materials, chemical cleaners still increase the specific gravity of water and slow-flushing velocity, interfering with performance.

Maintenance Checklist for Water Efficient Gravity Flush and Flush Valve (Flushometer) Toilets

Check for leaks every six months
Have a certified plumber address leaks once discovered
Adjust float valve to use as little water as possible without impeding waste removal or violating the manufacturer's recommendations
Periodically replace valves and ballcocks

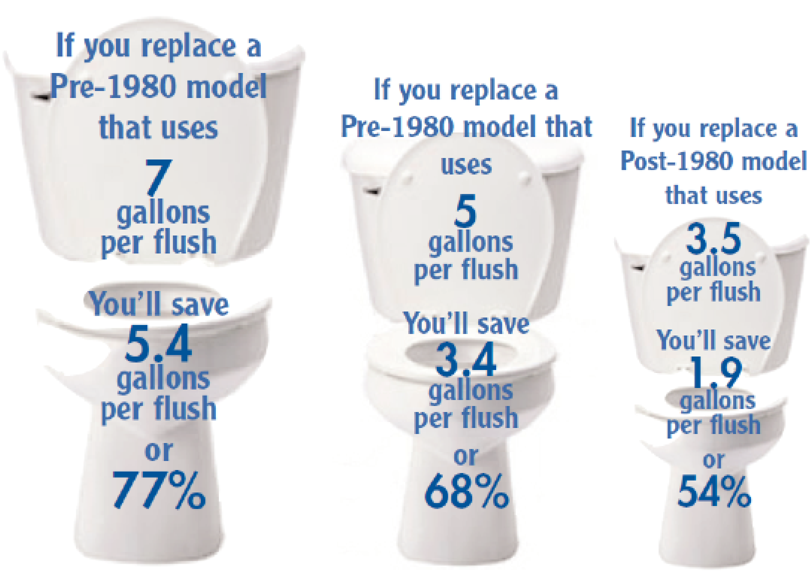
5.2.4 Safety

As is the case with routine plumbing installation, proper safety measures should be adopted for the installation of water- efficient toilet fixtures. Their direct usage, however, presents no known safety risks to persons.

5.2.5 Cost

The choice to retrofit based on cost recovery from water savings can be easily calculated in Jamaica based on NWC water rates and the price of the toilet, including installation.

HOW MUCH WATER DOES INSTALLING A 1.6 GALLON TOILET SAVE?



Whether you replace one toilet in a single bathroom or several hundred toilets in a large commercial or residential complex, you can expect to see significant savings. For example, replacing a typical 3.5 gallon toilet with a 1.6 gallon model will save a family of four 11,096 gallons per year. That's a 54% reduction in toilet water use. The more water the toilet you're replacing uses, the more you'll save.

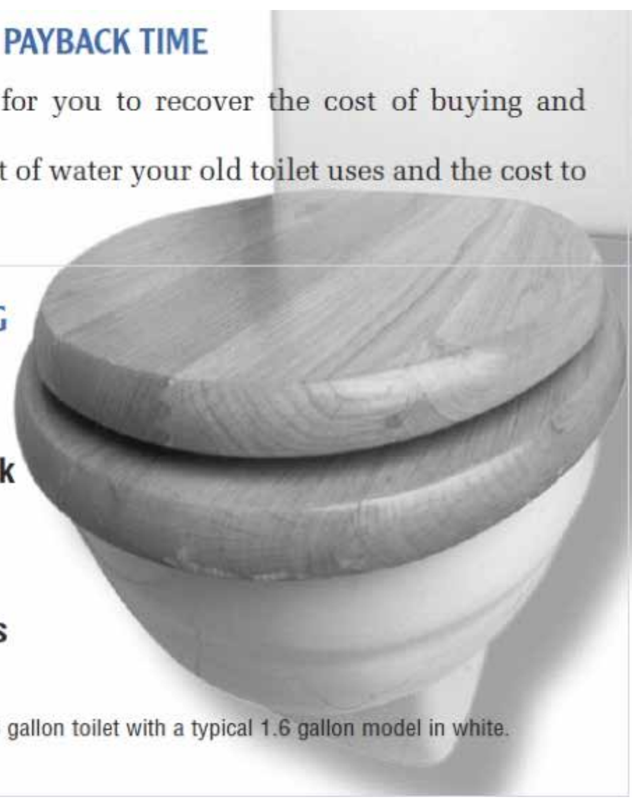
YEARLY SAVINGS FOR A FAMILY OF FOUR FROM SWITCHING TO AN ULTRA LOW FLUSH TOILET

Gallons per flush		Daily Flushes		People in household		Days in a year		Average cost of 1,000 gallons water and sewer		1,000 gallons		Cost per year
3.5 gallon (old model)*	X	4	X	4	X	365	X	$7.00	÷	1,000	=	$143.00
1.6 gallon (Ultra Low Flush Model)	X	4	X	4	X	365	X	$7.00	÷	1,000	=	$65.00
*without a toilet dam								Yearly Savings with the Ultra Low Flush Toilet:			=	$ 78.00

CALCULATE YOUR PAYBACK TIME

Your payback time is the time it will take for you to recover the cost of buying and installing an ultra low flush toilet.

Your payback time will depend on the amount of water your old toilet uses and the cost to purchase and install a 1.6 gallon model.



SAMPLE PAYBACK TIME FOR SWITCHING TO AN ULTRA LOW FLUSH TOILET

Approximate Installation Cost		Yearly Savings		Payback Time
$260.00	÷	$78.00	=	3.3 years

Installation cost includes labor and materials for replacing a 3.5 gallon toilet with a typical 1.6 gallon model in white.

Water User	Toilet
Conventional water usage rate	≥ 1.6 - 3.5 GPF
Efficient Water usage rate	0.8 - 1.28 GPF
Details and Benefits	Tank type toilet (HET)
Savings	Average 60%
Costs (Approximate, without installation)	
Tile City and Home Centre	$28,999
Active Home Centre	$13,900
Unique Living	$29,000
Instant Save Conservation	$30,000

**Basic installation costs average approximately 5,000*

5.2.6 Possible Inconvenience for Water Efficient Toilets-Clogs and Stoppages

A key question usually asked by householders is - 'does the installation of high-efficiency toilets ('HET') lead to insuffi- cient wastewater flows to move solid waste down building drain lines and sewers, resulting in clogs and stoppages?' The answer to that question is 'no'.

Reduced water demands from conservation measures further reduce wastewater flows, but thus far there are no verified instances of high-efficiency toilets causing building drain lines or municipal sewer systems to experience blockages.

Water and wastewater utility and plumbing industry research has consistently reported that low-volume (1.6 gpf) and high-efficiency (1.28 gpf) toilets are not causing, nor are they leading to, an increase in drain line clogs or sewer system blockages. For example, a 2005 study of the capacity of building drain lines to flush 1.28 gpf toilets that was sponsored by several Canadian federal agencies and water and wastewater utilities determined that some toilets flushing at even only one gallon provide sufficient water volume to move wastes down drain lines. Further, EPA's WaterSense programme, which sets high standards for the performance of high-efficiency toilets and other fixtures, reports:

> "With regard to municipal sewer lines, the transport of waste has not proven to be an issue of concern in those areas with a concentration of high-efficiency toilets. Supplementary wastewater flows from other end-uses are always sufficient to move solids through the system. Furthermore, some wastewater utilities are co-funding and sponsoring the toilet replacement programs and other water efficiency initiatives of the water utilities for the very purpose of reducing sewer flows to their treatment plants."

Though HET and low-volume toilets have not been found to adversely affect solid waste transport in building drain lines and sewers, research in Australia and Europe indicates that in the future, the combination of significantly reduced wastewater flows from a wide array of high-efficiency fixtures, appliances, and equipment might result in drain line transport problems in some types of building drain lines. This is, however, less likely in sewers.

Based on research conducted in Australia, some types of building drainage configurations may not always have sufficient liquid flows to transport solid waste at a normal rate. Though not yet actually borne out by actual experience, there is a theoretical potential for a drain line clog. This potential problem is unlikely to occur in the drain lines of single-family homes because of the presence of long duration flows from other fixtures and appliances, such as showerheads and washing machines.

WORKING TO ADDRESS FUTURE PROBLEMS

Plumbing research engineers and related professionals do not attribute water-efficient toilets alone to be the source of potential future waste transport problems in building drain-lines and sewers. Problematic plumbing designs, isolated horizontal drain lines, and significantly reduced flows from multiple other fixtures and appliances would likely also have to be present for stoppages to occur. Thus, plumbing engineer researchers are mindful of the theoretical potential for such conditions and are now working to address future problems if they do occur.

To mitigate possible future solid waste transport problems in building drain lines with much-reduced flows, the following is being recommended:

- In existing buildings, determine the minimum wastewater flow requirements for solid waste transport in the building's drain line prior to the installation of new high-efficiency appliances, fixtures, and other water using equipment. For example, commercial buildings with isolated high-efficiency toilets that provide most of the wastewater carrying solid waste down isolated long, horizontal drain lines running to the sewer may be potential trouble spots that will require adjustments to the plumbing system

- For new buildings, project carefully water and wastewater flow requirements when water-efficient equipment, appliances, and fixtures will be installed. Be sure to use updated flow specifications – not necessarily standard design criteria that may be outdated – when specifying pipe sizes, as approved by the code or other authority having jurisdiction.

- Rectify problematic building drain line flows by targeted adjustments to flows and composition, possibly including:

- Installation of one or more higher-volume fixtures at the beginning of an isolated drain line (farthest from the sewer) to provide additional flows to help move solid waste down the drain line.

- Installation of a timer on the automatic flush valve for one or more high-efficiency toilets and/or urinals installed at the farthest end of the isolated horizontal run. These timed, extra flushes will provide periodic surges of water to facilitate solids' transport down the drain line and to the sewer.

- Changing the type of toilet paper provided in restrooms. Toilet paper products vary considerably in their composition and rate of disintegration in wastewater, which, in some cases, affects solid waste transport.

- Develop new design criteria and sizing requirements for water and sanitary drain line pipes in buildings with multiple sources of reduced flows.

5.3 Water efficient shower heads

Bath and shower account for around 32% of water use within the home in Jamaica. The use of efficient showerheads is, therefore, the next great opportunity in reducing water consumption within the home. The least-cost water demand management option is in the retrofitting of standard showerheads with high-efficiency showerheads (HES). The regular non-efficient showerheads can use as much as 15-25 litres of water per minute. HES can use as little as 6-7 litres per minute with a category that can be called medium-efficient shower heads clocking in at around 9-15 litres per minute. There are more than 30 different high-efficiency showerheads available. As demonstrated in Australia, the changeover from non-efficient showerheads to HES can yield savings in water consumption anywhere between 20%-54% *(Willis, et al. 2013)*.

Given the connection with the adaptation of water - efficient technologies and the effect this has on end-user conservation habits, it must be noted that research found within the United States and Canada that households with low-flow showerheads increase their shower times *(Pérez-Urdialesa and García-Valiñas 2016)*. The number of persons per household was a significant factor in determining the amount of water used for showers and baths. Water use for showers and baths increased with household size and children. Household income has been shown to be related to how much water is consumed. Higher household incomes consume more water during showers than households with lower incomes. This suggests that targeting households with higher incomes should be a strategy in high-efficiency showerhead adoption. The reduction in water demand would yield a payback in around half a year for high-efficient showerheads unlike the three-year waiting periods to see a payback for low-flow or dual-flush toilets.

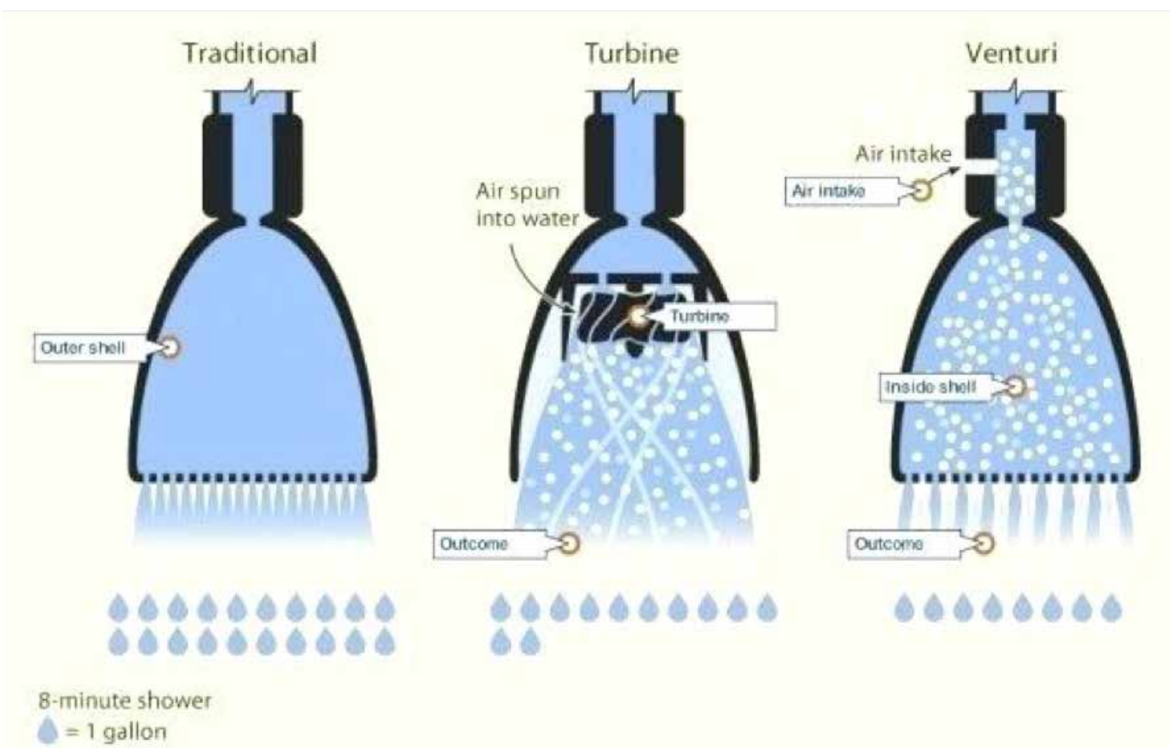


Figure 4 Types of Showerheads and their Efficiency. Retrieved from http://cacilesabo.top/gaspol/

5.3.1 Jamaican Design Considerations

No minimum design standards exist for high-efficiency showerheads in Jamaica. The flow rates below have been adopted from the USEPA's WaterSense® programme and sets out some proposed minimum standards for high- efficiency showerheads in Jamaica.

STANDARDS FOR HIGH EFFICIENCY SHOWERHEADS IN JAMAICA

Showerhead Rated Flow rate (maximum)	Maximum Allowable Flow Rate		
	80 psi	**45 psi**	**20 psi**
9.0 lpm	5.7 lpm	5.7 lpm	4.5 lpm
8.75 lpm	4.9 lpm	4.9 lpm	4.2 lpm
8.5 lpm	4.2 lpm	4.2 lpm	3.4 lpm
8.0 lpm	3.0 lpm	3.0 lpm	2.3 lpm

5.3.2 Installation

STEP 1:

With the shower taps turned off (no need to cut off the water supply to the entire house), unscrew the showerhead.

STEP 2:

Clean and dry the pipe threads and then wrap three layers of thread tape around them.

STEP 3:

Screw the new showerhead on (don't over tighten). Run the shower for a few seconds to check for leaks. Tighten only if necessary.

5.3.3 Use & Maintenance

Jamaica's underground basins are extremely rich in calcium carbonate. Limescale (CaCO3) build-up within plumbing systems is a critical maintenance issue to be dealt with, as a significant percentage of the country's potable supply comes from underground sources.

High-efficiency showerheads must be periodically inspected for scale build-up to ensure flow is not restricted. Cleaning products designed to dissolve scale from showerheads with build-up should be used. Also, water softeners and filtration systems provide critical savings and insurance against frequent, costly repairs, and infrastructure renovation.

Do not attempt to bore holes in the showerhead or manually remove scale build-up, as this can lead to increased water use or cause performance problems.

Scale build-up can cause showerhead performance issues or an impeded flow, which reduces user comfort. Keeping water-efficient showerheads clean and performing well can help ensure user satisfaction.

5.3.4 Safety

All showerheads, including high-efficiency ones, need to fit into a properly designed plumbing system to provide maximum performance and safety. Also, when purchasing a high-efficiency showerhead and automatic-compensating mixing valve, ensure they are marked with the same flow rate at a pressure of 45 psi.

5.3.5 Cost

Water User	Showerhead
Conventional water usage rate	≥ 2.5 gpm
Efficient Water usage rate	1.25-2.0 gpm
Details and Benefits Pressure compensation feature available. Small change, big savings. Saves energy used for heating water.	
Savings	Up to 50%
Costs (Approximate)	$2,000

5.3.6 Possible Inconveniences for Householders

When maintained well, high-efficiency showerheads present no known inconveniences for householders.

5.4 Water efficient faucets and low flow faucet aerators

WATER EFFICIENT FAUCETS

Miscellaneous faucet use is the most frequent water use in homes. Faucets tend to have a flow rate of around 7-9 litres per minute, just around the same as the high-efficient showers identified above. However, faucet use includes everything from filling drinking glasses, filling buckets for cleaning, cooking, brushing teeth and washing hands. Jamaica's data on the different use of water within the home is very much similar to the global general trend. Toilets lead the list, followed by the shower, then laundry and dishwashing closely behind. While not explicit in the National Water Commission data, faucets and their various uses would be the next candidate based on the pattern seen globally. When it comes to faucets, each works a little differently, unlike, say, toilets or showerheads. There are five types of faucets to look at and each works differently.

COMPRESSION FAUCETS

Compression faucets are the oldest kind. These have handles you turn just like a screw. You tighten and untighten these handles manually by rotating them to let water flow out of the faucet. The stem of the handle has a washer on the end that goes over a valve when tightened. The stem's washer compresses over the seat of the valve and cuts off the water. Loosening the handle raises the washer and allows water to flow. Faucets like this are prone to leaking as the washer is worn.

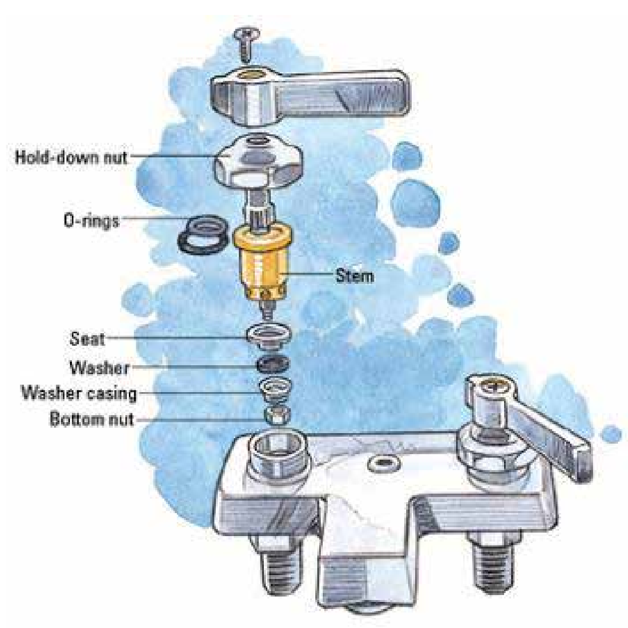


Figure 5 Traditional Faucet Design with Washer. Retrieved from https://plumbertotherescue.com.au/news/diy-fix-leaky-faucets.html

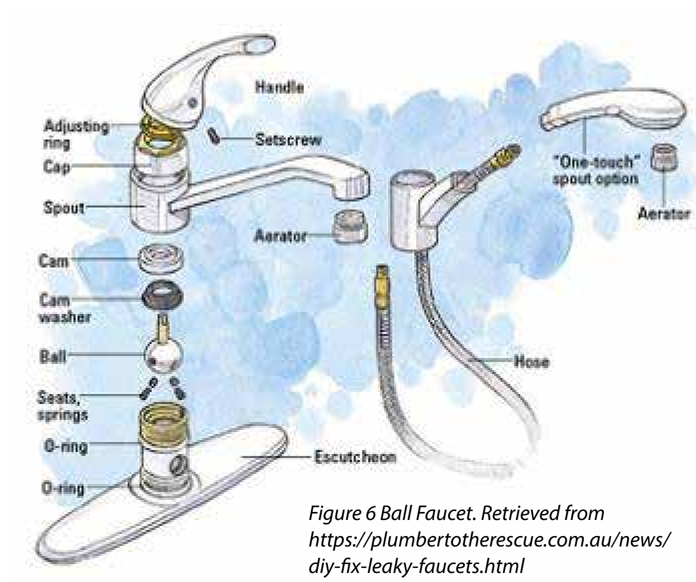


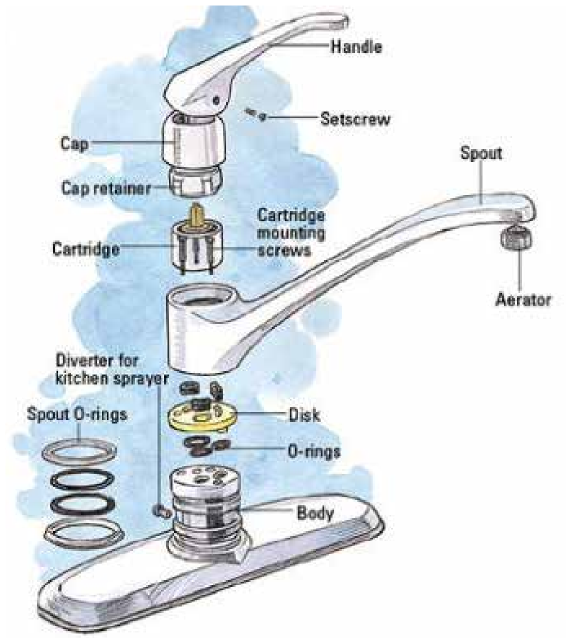
Figure 6 Ball Faucet. Retrieved from https://plumbertotherescue.com.au/news/diy-fix-leaky-faucets.html

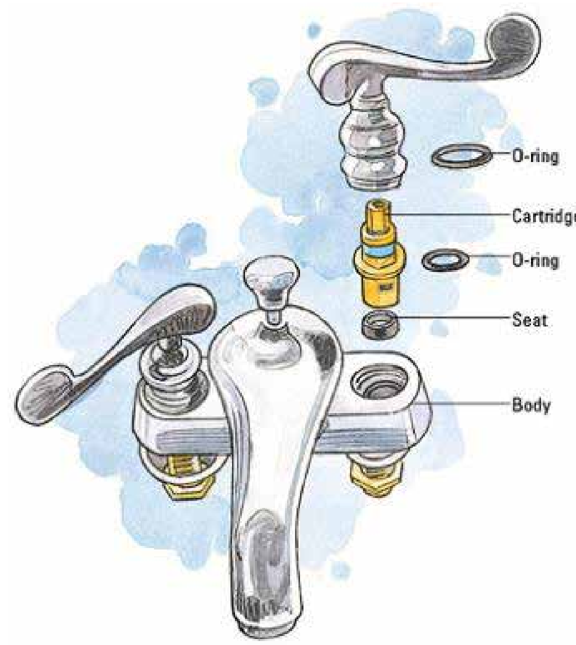
BALL FAUCETS

Ball faucets are the first washerless faucet. Faucets that can rotate semi-freely up and down and from side to side are probably ball faucets. A ball faucet's handle controls a rotating ball called the lever ball assembly. Flow rate and pressure of the water depend on where you position the ball faucet handle. The lever ball assembly is located inside the faucet's body and sits on a system of springs and inlets directly over the opening where water flows through the faucet. This ball has chambers and slots built into it. Manoeuvring the ball, you align the slots in the ball with the inlet seats in the faucet and, therefore, control how water flows through the faucet.

DISC FAUCETS

Disc faucets are considerably more durable than either compression or ball faucets. Disc faucet handles move up and down and side to side like ball faucets, but they usually don't have as much free motion. The cylindrical body of the faucet contains two ceramic discs: an upper disc and one lower disc. The upper disc rotates with the handle, while the lower disc stays locked in place. Together, these two discs form a watertight seal when you close the faucet, and when you open the faucet to let water flow, the upper disc separates from the lower disk. Water passes through the newly created gap.





CARTRIDGE FAUCETS

Cartridge faucets can have either one or two handles. You don't have to rotate the faucet handles to control water flow. Instead, you can simply turn a cartridge faucet handle to start the water flow. The handle should rotate from 'off' to 'on' in one smooth, easy motion with single-handle cartridge faucets move up and down to control water flow. Cartridge faucets contain a hollow metal cartridge inside the body of the faucet. This hollow cartridge seals the faucet, blocking water flow. When you open the faucet, you push the cartridge forward, which no longer covers the water lines.

Figure 7 Disk Faucet (left) and Cartridge Faucet (Right). Retrieved from https://plumbertotherescue.com.au/news/diy-fix-leaky-faucets.html

METERING FAUCETS

Metering faucets are the more recent of the types and are specifically designed to ensure faucets are off as much as possible. The previous designs can be thought of as being driven by leak prevention. There are low-tech and high-tech metering faucets. The push-button faucets are the low-tech versions of this type. The button-handle is pushed and water flows for a predetermined amount of time for hand-washing purposes. Typically, 12 seconds is considered sufficient time for hand-washing, but the timing on these faucets can be adjusted to have water flow for less time. Once the water stops flowing, the button-handle has to be pressed again to start another cycle. The more high-tech version of this type is the Auto-Sensor. This version only turns on when hands are under the nozzle. A motion sensor determines when this faucet is turned on. They can work just like the push button in that there are only on for a predetermined period or they stay on as long as hands are under the nozzle. As soon as the hands are withdrawn, the faucet is turned off.

Figure 8 Sensor Activated Faucet.

As far as faucets go, when it comes to conserving water there are just two rules to follow.

i. Make sure faucets do not drip or leak.

ii. Turn off faucets and keep water running only when necessary as much as possible.

The infrastructure in most of the old houses in Jamaica still has compression-type faucets that are prone to leaking. Retrofitting homes to use more faucets that do not have washers would be a good step in water-conservation efforts. The only drawback to this is that these faucets still rely on the habits of the user to not leave them running while not in use. While auto-sensor faucets are more expensive, these faucets mitigate water wastage via unattended running faucets. Whereas it would be more cost effective to use a cartridge, disc or ball faucet within homes, using metered faucets in public spaces should work out more efficiently than any of the other kind.

LOW FLOW FAUCET AERATORS

An aerator is an accessory that one can add to the tip of a faucet to create a stream delivering a mixture of water and air. They function in multiple ways that maximise the efficient use of water. In particular, aerators shape water from faucet spouts into straight and evenly pressured streams. In the case of kitchen uses, this reduces the amount of water needed for washing plates by using the pressure of the stream in helping to remove food particles. Another use of aerators is to reduce the flow rate of faucets and thus conserve water. With the standard faucet having a flow rate of 7-9 litres per minute, the addition of low-flow aerators can reduce that flow rate down to around 6 litres per minute.

Since aerators mix air into the water, we get the same effect of having a high-pressure stream with less volume of water being used, since the volume is substituted with air. As such, aerators are a cheap and common solution to reducing volume but maintaining flow rate (Beala, Bertonea and Stewart 2012). Strategies using faucet aerators have been shown to be able to cause major reduction in domestic water use while reducing wastewater production *(Siegrist 1983)*.

Figure 9 Aerator nozzle in white attached to faucet. Retrieved from https://www.youtube.com/watch?v=AWRxhbKWvZk

5.4.1 Jamaican Design Considerations

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STANDARDS FOR HIGH EFFICIENCY SHOWERHEADS IN JAMAICA

Faucet Rated Flow rate (maximum)	Maximum Allowable Flow Rate		
	80 psi	45 psi	20 psi
9.0 lpm	5.7 lpm	5.7 lpm	4.5 lpm
8.75 lpm	4.9 lpm	4.9 lpm	4.2 lpm
8.5 lpm	4.2 lpm	4.2 lpm	3.4 lpm
8.0 lpm	3.0 lpm	3.0 lpm	2.3 lpm

5.4.2 Installation

A licensed plumbing professional should undertake faucet installation. Different faucet types and brands have different installation instructions that should be followed carefully.

5.4.3 Use & Maintenance: Cleaning Tips

FAUCET CLEANING AND MAINTENANCE

Cleaning & maintaining finish	• Wipe your faucet with a damp cloth and mild household cleanser. • Dry with a soft cloth to retain lustre and shine. • Remove hard-water stains with a 50/50 solution of white vinegar and water. • Rinse thoroughly with water afterwards.
Limescale and mineral deposit removal	If using a mild household cleanser doesn't do the job, place a cloth soaked in white vinegar over the deposits for several hours, then try the mild cleanser again. ***Note:*** Drying the faucet with a soft cloth after each use will help prevent mineral deposits.
Mineral deposit removal from aerator	• Unscrew aerator or use the special tool that came with your faucet. If your aerator has a separate black sealing gasket, rinse it in clear water. • Soak the aerator in a 50/50 vinegar and water solution for several hours. • Flush the aerator with water. • Rub stubborn deposits with a toothbrush.

5.4.4 Safety

The use of water-efficient faucets and low-flow aerators present no know safety issues if used correctly.

5.4.5 Cost

Water User	Kitchen faucet aerator
Conventional water usage rate	≥ 2.2 gpm
Efficient Water usage rate	1.0-1.5 gpm
Details and Benefits Pressure compensation feature available. Small change, big savings	
Savings	Up to 55%
Costs (Approximate)	$650

Water User	Bathroom faucet aerator
Conventional water usage rate	≥ 2.0 gpm
Efficient Water usage rate	0.5-1.5 gpm
Details and Benefits Pressure compensation feature available. Small change, big savings	
Savings	Up to 75%
Costs (Approximate)	$400

5.4.6 Possible Inconveniences for Householders

Depending what water is being used for, aerators may or may not be a good idea. Below are some general rules to gauge your needs:

1. **Volume-based tasks:** If water is used to fill a container (e.g. pasta pots or dishwashing sinks) aerators will not save water or energy. Instead they will increase the amount of time it takes to complete the task. In this case, don't use an aerator.

2. **Flow-based tasks:** If running water is used for washing (e.g., hands, dishes or food), then an aerator is the perfect solution. In this case, use a 0.5 gpm aerator.

3. **Combination of tasks:** If water is used both for flow- and volume-based tasks (e.g., household kitchen sink), you need to find a happy medium. A higher-flow aerator will save energy and water without hindering volume-based tasks. In this case, use a 1.0 gpm aerator.

5.5 Water efficient washing machines

Globally, clothes washing is the third highest consumer of household water just after the shower. The situation in Jamaica follows this same trend with laundry constituting around 14% of water use within the home.

Washing machine usage is not very popular within the average single-family household of Jamaica. However, they are a significant feature of communal use in building complex washrooms. Here, they have wide access to a large and mixed demographic audience and as such become a means of considerate water loss. Globally, clothes washing is the third highest consumer of household water just after the shower. The situation in Jamaica follows this same trend, with laundry constituting around 14% of water use within the home.

The Commonwealth of Australia (2008) states that water-efficient washing machines can use a third of the water required by an inefficient model. The total volume of water used by a washing machine can range from 76 litres to 189 litres, for one cycle. Given the wide variety of heating, water connections, and loading configurations of clothes washers, the water, and energy demands can vary markedly between machines. In Europe, studies found that around 15% of residential water supply is used in washing machines, not dissimilar from the laundry use in Jamaica of 14%. More so, case studies in Europe found that there would be a 32% water savings if inefficient washing machines were changed out for more efficient ones *(Elliott, et al. 2011)*.

On the other hand, studies in Australia also found that washing machines were associated with higher water use and therefore less water conservation *(Fielding, et al 2012, 9)*. Surprising as this was, not all water-efficient appliances have the expected effects. Behavioural habits are a big part of conservation efforts and that is why moral suasion is a big part of water-conservation efforts. A possible explanation for such an increase in water usage after installing washing machines that are more efficient is a change in mindset, where people feel they can be less vigilant

Figure 10 Traditional Washer (left) vs High Efficiency Washer (Right). Retrieved from https://tigermechanical.net/appliance-repair/why-is-there-a-low-water-level-on-he-washer/

and even use more of a resource because they have efficient appliances *(Midden, Kaiser and McCalley 2007)*. This particular finding of increased water consumption when washing machines that are more efficient are used is not unique to Australia. Similar effects were found in behavioural analyses of conservation practices across OECD countries *(Pérez-Urdialesa and García-Valiñas 2016)*. Pérez also noted that the amount of water used by all possible appliances in single-family households from different municipalities in the US and Canada showed that households with low-flow showerheads increase their shower times.

Water savings obtained by using efficient water-using technologies may differ depending on the device or appliance analysed. Households may invest in a particular efficient appliance or demonstrate a specific water-conservation habit because of the resulting energy savings rather than the decrease in water use, because of the lower relative price of water *(Pérez-Urdialesa and García-Valiñas 2016)*. A four-year longitudinal study on water- efficiency measures on household demand also found higher total washing frequency has been reported after receiving a new machine *(Leea, Tansela and Balbinb)*.

Devices such as this, unlike toilets, showerheads and faucets, can be viewed as luxury household items. As such, habits and socio-economic behaviours take on a greater role in driving water efficiency in homes. Installation of these appliances should be accompanied by intense educational and social awareness campaigns targeted at instilling water-conserving behaviours.

5.5.1 Jamaican Design Considerations

The USEPA's WaterSense® and Energy Star® set out design specifications for water efficient washing machines. Clothes washers that use these standards (or equivalent) should be adopted within the Jamaican marketplace.

5.5.2 Installation

Though fairly easy to install, water-efficient washing machines should be installed by a licensed plumber who can guarantee work. Basic steps are:

i. **Connect the standpipe:** Install a standpipe to a P-trap connected to the drainage and vent system. The standpipe must have a greater diameter than the hose, and the top should be above the washer's water level to prevent overflow.

ii. **Hook Up the Washer Supply Hoses:** Connect the hot and cold water lines using water pump pliers. Turn on the water valves and run the clothes washer. If there are any leaks, tighten the connections.

iii. Level the Clothes Washer: Once the machine is in place, you'll want to make sure it's seated securely on the floor and is perfectly level to keep it from 'walking' and banging loudly while you're doing the family wash. Place a carpenter's level or a bubble level on top of the washer. Level the unit by adjusting the legs and securing the locknuts against the frame. Last, be sure to plug in electrical cord into the socket (they typically are installed directly behind the washer on the back wall). Ensure all functions work.

5.5.3 Use & Maintenance

Below are some key steps to maintaining your water efficient washing machine.

1. REPLACE THE WATER HOSES.

Check hoses regularly for bulging, cracking, fraying, and leaks around the ends. Replace the hose if a problem is found or every three to five years as part of a proactive maintenance programme.

2. MOVE THE MACHINE.

Check that there are at least four inches between your washing machine and the wall. This prevents hoses from kinking.

3. KEEP THE MACHINE LEVEL.

A washing machine that's off kilter can vibrate, rock, or 'walk' across the floor during the spin cycle, which can damage the floor or the machine.
Balance the washer by turning the legs clockwise to lower it, and counterclockwise to raise it.

4. CLEAN THE LINT FILTER.

Depending on your machine, the lint collector may be located in the agitator tube, which is the centre column of most machines, or near the top of the washtub.
Keep it clean to help your washer run efficiently.

5. WASH THE WASHING MACHINE.

Rinse away soap residue and buildup by running store-bought washing machine cleaner, or a solution of hot water, vinegar, and baking soda through an empty load.

6. PREVENT MUSTY ODORS AND MILDEW.

Leave the washer lid or door open between loads to dry out the unit and keep it smelling fresh. On frontloading washers, wipe down the rubber seal around the door after doing your laundry.

7. MEASURE YOUR DETERGENT.

Read the appliance instruction manual to make sure you use the correct type and amount of detergent for your machine. Too much soap can leave residue on your clothes and cause excess wear and tear on your washer, and high-efficiency washers require a special, low-sudsing detergent.

8. DON'T OVERLOAD THE MACHINE.

Use the appropriate amount of water for the size of the load. Wash heavy or bulky items in small loads since these are harder on the appliance.

9. ADD A DRIP PAN UNDERNEATH YOUR WASHING MACHINE.

This is an important addition to an upstairs laundry room, since water leaks could damage the floors below it.

5.5.4 Safety

Water efficient washing machines, once used according to manufacturer's specifications, present no known safety risks in their usage.

5.5.5 Cost

Water User: Horizontal-axis (front-loading) clothes washers	
Conventional water usage rate: Older washers use up to 40 gallons per load.	
Efficient Water usage rate: Use between 15 and 25 gallons per load.	
Details and Benefits Choose Energy Star or Water Label Clothes are tumbled through a small volume of water in the bottom of the drum.	
Savings	Up to 55%
Costs (Approximate)	$60,000-$90,000

5.5.6 Possible Inconveniences for Householders

The use of water-efficient washing machines presents no known inconveniences for householders.

5.5 Water efficient washing machines

6%

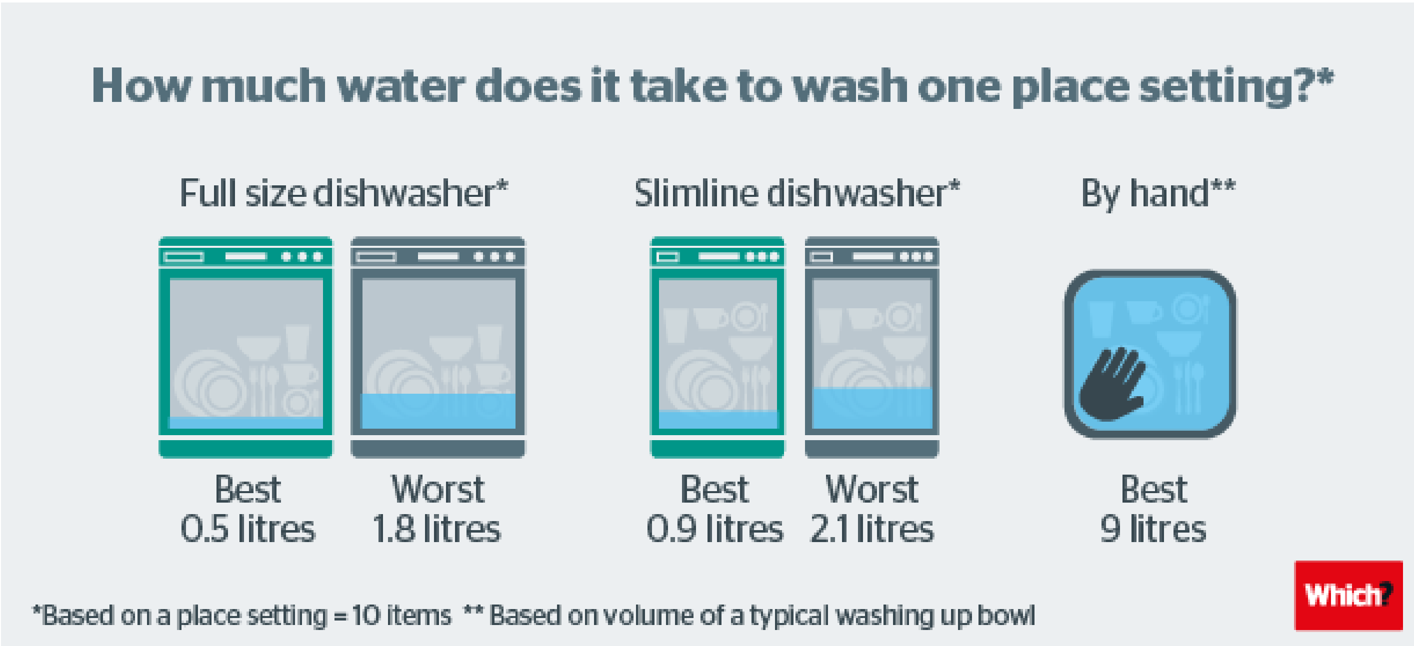
Dishwashing uses around 6% of the water in the average Jamaican home with one installed.

Dishwashers use around 6% of the water in the average Jamaican home with one installed. The average dishwasher uses between 30-43 litres of water. They have a flow rate of around 5 litres per minute. Dishwashers are found to be correlated with household income, which means that the higher the income of the household, the more likely it is that they have a dishwasher.

Dishwashers are not very popular appliances to find in the typical Jamaican home either. Regardless, efficient dishwashers are associated with lower water use and, therefore, greater water conservation. Unlike clothes-washing machines, dishwashers are usually a single connection to a cold-water tap, with an internal element used to heat the water. The increase in use of dishwashers within the market place has been found to be more about the energy savings rather than water efficiency (Stamminger 2011). This is not to say that they aren't water efficient at all. There is a 7% decrease in water use associated with dishwasher use in North America.

The relationship between income class and water consumption in Jamaica positions efficient dishwashers and efficient washing machines as targeted technologies for high-income homes - not just because these kinds of households would have these appliances but also to instil water-conservation ethos within the demography that consumes the most water on the island. A behaviour-change approach is integral to how one goes about implementing these systems on a whole, but especially so for both washing machines and dishwashers.

Figure 11 Diswashing Options and Water Use. Retrieved from https://www.which.co.uk/reviews/dishwashers/article/which-dishwasher/how-to-buy-the-best-dishwasher



5.6.1 Jamaican Design Considerations

As a general guide, water-efficient dishwashers should use no more than 3.8 litres (approximately 1 gallon) per cycle.

5.6.2 Installation

A licensed plumber who can guarantee work done should be used to install your water efficient dishwasher.

5.6.3 Use & Maintenance

A dishwasher is generally a low-maintenance appliance. Below are some basic tips for keeping your dishwasher running in tip-top shape:

1. MAKE SURE YOUR DISHWASHER IS LEVEL.

If your dishwasher isn't level, it could leak. To check, open the door and place an air-bubble level along the edge inside. If the dishwasher isn't level, raise or lower either side by adjusting its 'feet', or add a wedge to balance correctly.

2. CHECK GASKETS FOR CRACKS AND DETERIORATION.

These are the rubber or plastic seals along the dishwasher door that provides a watertight seal when you close. If you start noticing water around your dishwasher, it could be caused by faulty gaskets. If the gasket is damaged, remove it by unscrewing it or prying it out with a screwdriver. You can get a replacement gasket at a hardware store or order one from the manufacturer. Before installing the new gasket, soak it in hot water to make it more flexible.

3. CHECK SPRAYER ARM FOR CLOGS.

Over time, food particles, mineral deposits, and other debris can clog the holes in the sprayer arm. It is essential to clean these small holes from time to time to enable the dishwasher to work more efficiently. Remove the sprayer arm periodically and soak in warm vinegar for a few hours to loosen any obstruction. Then clean out each spray hole with an awl or a pipe cleaner.

4. CHECK AND CLEAN SCREENS AND FILTERS.

Your dishwasher should have a screen or filter located near the bottom of the dishwasher above the food drain to catch any large food or debris. They need to be cleaned regularly to avoid clogs (at least every other week). Your dishwasher owner's manual should provide instructions for removing and cleaning the filter. If the filter has holes, it needs to be replaced in order to prevent harm to other parts of the dishwasher. Also, inspect and clear out any food or debris that might be trapped in the food drain.

5. INVEST IN A REPAIR KIT.

Notice any exposed metal, nicks or corrosion on your dish racks? These can cause rust and stains to dishes and dishwasher walls. Most hardware stores sell repair kits that allow you to quickly mend worn or chipped plastic.

5.6.4 Safety

Below are some important dishwasher safety tips to keep in mind:

1. Place sharp utensils like knives and forks face down inside the utensils basket. Place the spoons up to allow more room for other utensils in the basket. This prevents you from cutting or piercing your skin when unloading your dishes after they have been cleaned.

2. When loading glassware inside the dishwasher, make sure to place them gently to prevent breaking/chipping. Glassware should be positioned inside the rack firmly where they don't rattle with each other once you start the wash cycle.

3. Avoid overloading dishes. Placing dishes beyond the maximum capacity of your dishwasher can cause a number of different issues like poorly cleaned dishes and chipped plates. Separate your dishes into batches and place them correctly inside the rack.

4. Allow your dishwasher to cool off after extended use. Prolonged usage of the dishwasher can cause the components to overheat and let out intense steam that could burn your skin. Before you take out your dishes, make sure the rack is cool to the touch to prevent skin burns.

5. Always make sure to close the dishwasher door when loading or unloading dishes to prevent tripping accidents.

6. Child-proof your dishwasher by adding a lock to help keep children away from the equipment when not in use.

7. Store dishwashing products such as detergent and rinse aid out of reach of children to prevent ingestion and accidental poisoning.

8. Read the instruction label when using detergents and rinse aid. Use only the recommended amount that's appropriate for your dishwasher.

9. Fill the dispenser cups only when you're going to use the dishwasher. Doing so will prevent children from reaching in and getting into the chemicals.

10. Avoid mixing dishwasher detergent with other cleaning chemicals. This prevents irritating fumes from forming that are dangerous when inhaled.

11. Keep the detergent and other dishwasher chemicals in their original containers with the labels intact so children won't confuse it for food, etc.

12. Don't wash non-stick pots and pans inside the dishwasher. The cleaning process can wear out the non-stick coating and cause it to flake off over time. Unless the cookware says it is dishwasher safe, avoid placing non-stick cookware inside the rack.

13. Check if your dishes are dishwasher safe. Dishwashers use high temperatures to clean and sanitise your dishes. Plastics tend to warp or become brittle over time so opt to hand wash them instead.

5.6.5 Cost

Water User: Water Efficient Dishwasher	
Conventional water usage rate: Hand washing and drying of an amount of dishes equivalent to a fully loaded automatic dishwasher (no cookware or bakeware) could use between 20 and 300 litres (5.3 and 79.3 US gal) of water.	
Efficient Water usage rate: Use up to 3.8 litres (approximately 1 gallon) per cycle.	
Details and Benefits Choose Energy Star or equivalent label.	
Savings At least 39% water savings compared to traditional hand washing.	
Costs (Approximate)	$80,000-$160,000

5.6.6 Possible Inconveniences for Householders

Water-efficient dishwashers present no known inconvenience for householders.

5.7 Leak detection technology

Leaks can be considered one of the largest obstacles to mitigating water loss in Jamaica.

10%

The National Water Commission attributes 10% of water loss in homes due to leaks.

91,000

At a rate of one drop per second, leaks can cost a home almost 91,000 litres of water loss over a lifetime of use (55-65 years).

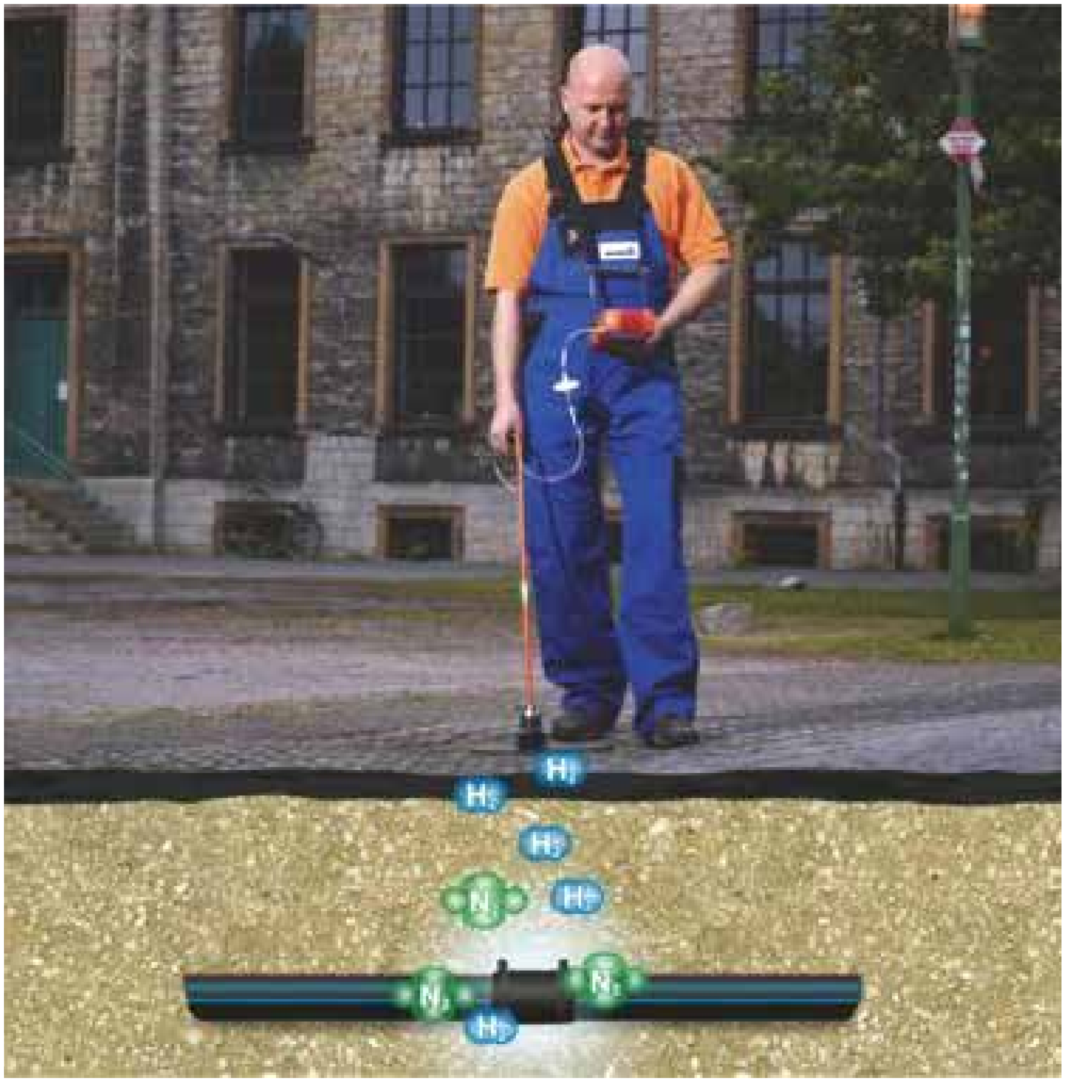


Figure 12 Portable Acoustic Leak Detector. . Retrieved from http://www.sewerin.co.uk/products/water-leak-location/vario-tec-460/

Leaks can be considered one of the largest obstacles to mitigating water loss in Jamaica. The National Water Commission attributes 10% of water loss in homes to leaks. At a rate of one drop per second, leaks can cost a home almost 91,000 litres of water loss over a lifetime of use (55-65 years). Conversely, the largest residential water-demand study done in Australia found that together with the replace- ment of inefficient fixtures (faucets), checking and repairing leaks, there was a 12% reduction in water use *(Turner, et al 2004)*. Here we see that leak detection technology can go a long way in reducing the time for checks and repairs to be done, cutting the amount of water loss each second.

Detection and repair of small leaks in a distribution system are critical functions of that system's operation and maintenance, yet they are often neglected. Breaks in large water mains may draw media attention and seem catastrophic, but failures such as that only account for 1% of water loss via leaks. Likewise, small leaks on the surface may be more easily identified, but it is the leaks that are underground that cause the most loss. Minor underground leaks can go undetected for months and even years. To put it differently, a small leak with a flow rate of 1 litre per minute would almost definitely go unnoticed for years, resulting in losses of over 500,000 litres of water per year. Leak detection technology can improve the ability of water utilities to respond quickly and repair leaks.

Before the implementation of any leak detection system, a water audit should be performed to quantify leakage and prioritise activities. The importance of this audit is so that one has an idea of where water is going missing along the system. Audits are usually done by monitoring the inputs of water into the system and matching back this information with customer use along the network of pipes, then resolving this information to identify zones with high leakages.

There are numerous technologies available for leak detection. The main categories of technology available are: acoustic, infrared thermography, chemical tracer, and mechanical methods.

Acoustic methods are able to recognise leaks based on the characteristic patterns of sound that leaks create. They have been and continue to be the most common leak detection systems. Using sound to detect leaks is more successful when the piping system is metallic. The sound becomes weak quickly when used on plastic and concrete pipes, making detection very difficult. Equipment such as ground microphones and acoustic loggers are the most commonly used leak detection technology. Ground microphones come with headsets connected to amplifiers as a unit small enough to fit inside the trunk of a car. Noise loggers are a specific type of acoustic leak-detection technology that includes a listening head and digital recorder in a single sensor, small enough to fit in the palm of a hand. They are usually installed directly unto the fittings of pipes.

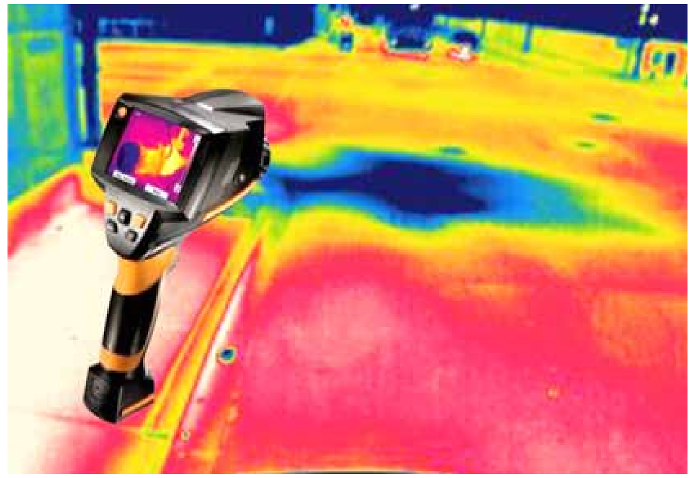


Figure 14 Handheld Infrared Leak Detector with Thermal display enlarged in background

Infrared thermography detects infrared energy emitted from an object, converts it to temperature, and displays an image of temperature distribution. This means that areas where there are water leakages will have warmer temperatures than the main pipe but cooler than the surrounding earth. Signs in how the temperature differs across the area will indicate where leaks are. Specific equipment in this category is thermographic cameras.

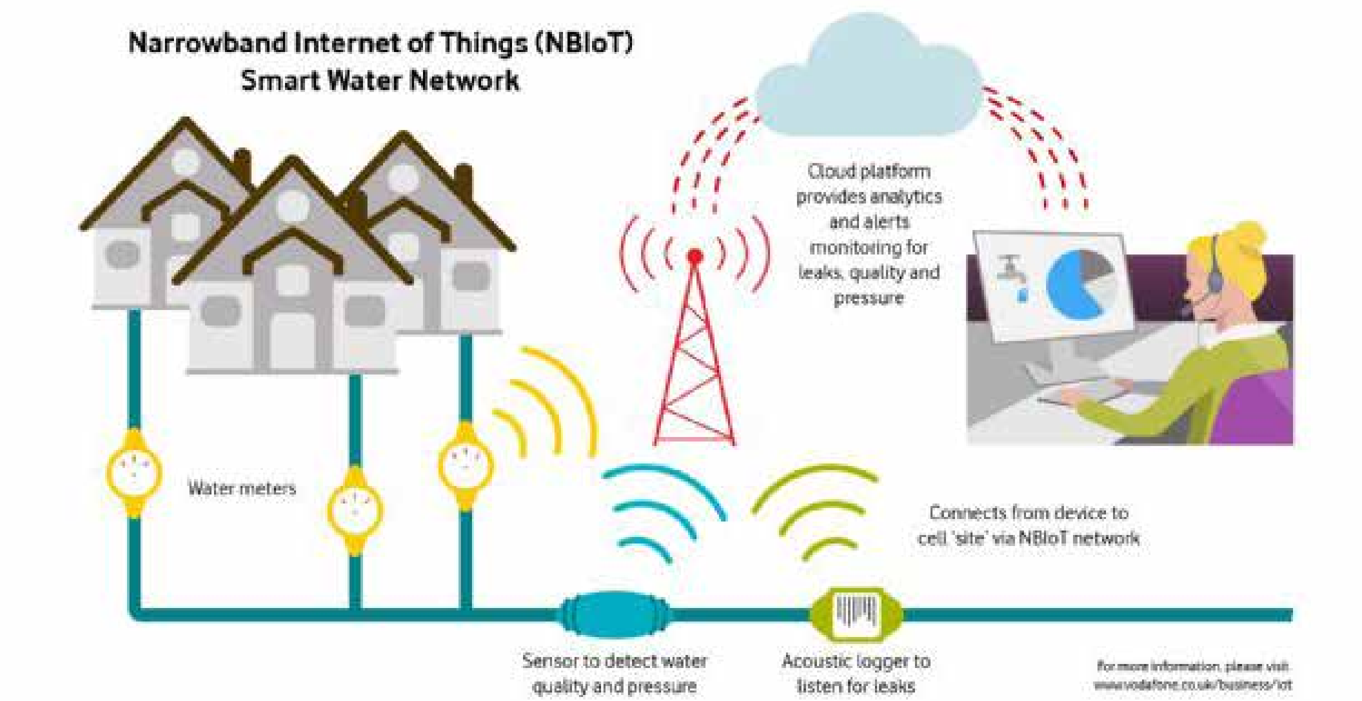


Figure 13 Acoustic Leak Detection Network using Acoustic Loggers. Retrieved from https://wwtonline.co.uk/news/sew-and-vodafone-pilot-nb-iot-leakage-solution

Other means of leak detection can involve the use of chemicals such as sodium 24 that produces a detectable burst of gamma and beta radiation. This signature can be read by a Geiger-Mueller counter. Sodium 24 is non-toxic to humans and poses no immediate threat. Once no radiation is detected, there is no leak. Finally, sodium 24 takes around 15 hours to completely decay and stop emitting gamma and beta radiation.

There are considerable other means of leak detection that get more technical in how they go about ascertaining leaks. Such means involve doing analyses of the data collected in a lab setting. The two categories outlined above are systems that can be used to identify leaks infield and does not take as much technical training to understand.

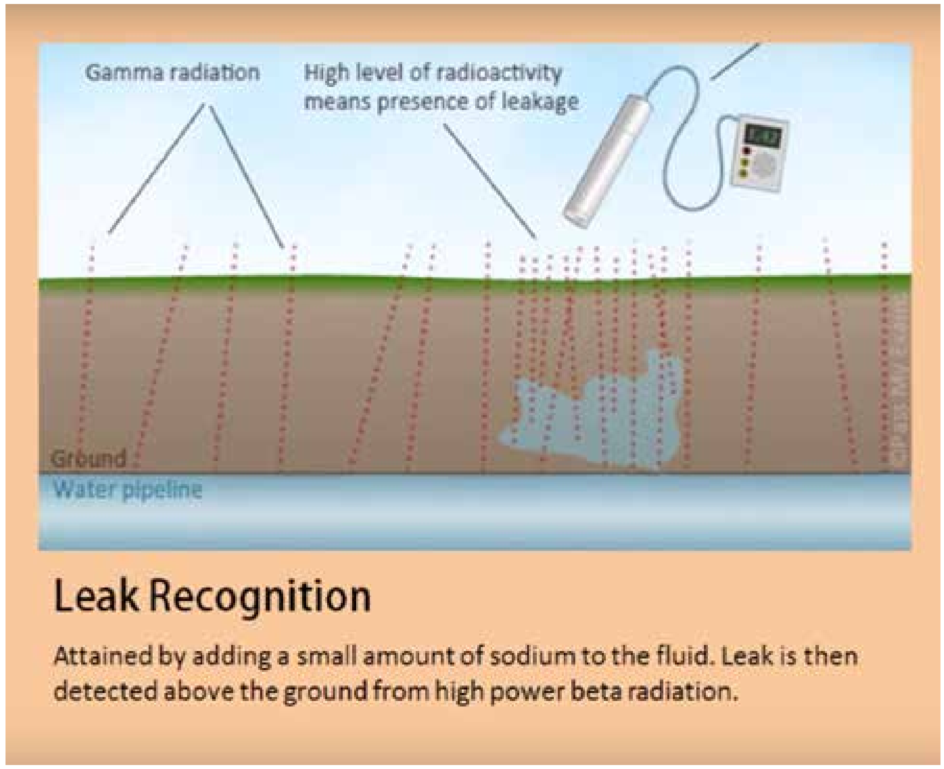


Figure 15 Illustration of Geiger counter detecting leak using Sodium 24. Retrieved from https://www.youtube.com/watch?v=Itd7b0q3tvo

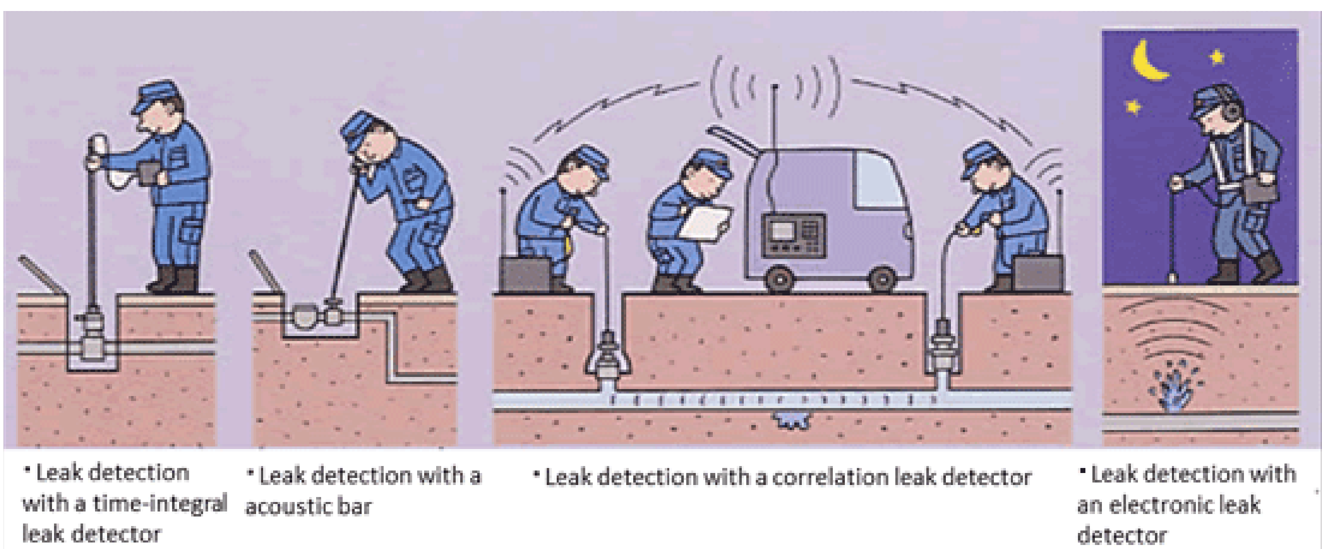


Figure 16 Some other methods of leak detection. Retrieved from https://www.tssk.jp/eng/service/antileak/

5.7.1 Design Considerations

Several varied design options exist for household leak detection. The simplest action to detect a leak in the home is to observe if the water bill suddenly goes up when the circumstances in the home have not changed. A way of confirming this is to turn off all the water appliances and observe the water meter. If the dials on it are turning, there is a leak somewhere. It may be possible to hear the hissing noise of water escaping. A search for the source of the sound will reveal the leak.

Water-flushed toilet systems can be checked by putting a few drops of food colouring in the water tank of the cistern, and 30 minutes later checking the water in the toilet bowl. If it has colour in it, the cistern is leaking.

Acoustic logger technology should be considered for leak detection within large housing developments.

5.7.2 Installation

Basic household leak detection does not require any 'installation'. Acoustic loggers are installed directly on to the fittings of a water pipe and should ideally be done during construction of a housing development in order to prevent re-excavation.

5.7.3 Costs

Basic household leak detection is behavioural and therefore has no cost. An individual acoustic logger will cost approximately J$55,000. Large housing developers should be mandated to ensure these are supplied and installed along with the water-supply network of each development.

Rainwater harvesting for use within urban green spaces has been a means of conserving household pipe water use in many countries.

5.8 Rainwater harvesting systems

Rainwater harvesting for use within urban green spaces has been a means of conserving household pipe water use in many countries. This water can be used to flush toilets, shower and for irrigation purposes. Water to meet drinking requirements (potable water) needs further processing and should come from the National Water Commission (NWC) or a Ministry of Health and Wellness-approved source. This guide will outline the key considerations for the design of a rainwater harvesting system for a typical Jamaican house, able to provide both potable and non-potable water.

Rainwater harvesting involves sequestering water from surfaces and storing it after some filtration process for later use.

One of the most common means and easily done is to harvest water from roofs, but water can be harvested from any surface such as a paved area or land runoff - although water harvested after coming in direct contact with the ground will be contaminated by debris and require more filtering. Another scale of rainwater harvesting that may not readily come to mind is that of aquifer recharge. This is achieved by building harvesting structures that direct water runoffs after rains into areas where it can percolate into the water table more easily. Water can also be channelled into areas creating artificial ponds.

Interestingly, artificial ponds created through rainwater harvesting can become a way of not only increasing the aesthetic appeal of housing developments but also act as a drainage system. Separate from the aesthetic value, there is also the cooling effect it will serve, given that housing developments are typically saturated with concrete pavements that have a high heat capacity. Creating artificial ponds via rainwater harvesting will enable enough water to stay on the surface and provide an overall cooling effect on the surrounding area.

The most immediately implementable rainwater harvesting system at the lowest cost to home owners is to use roof surfaces to capture and recycle water for bathrooms and laundry use. Bathroom and laundry are the two main areas of water consumption in Jamaica. This being so, the benefits of these kinds of water reuse efforts are almost immediate in how much water is being saved. Other countries also have bathroom and laundry duties being the two main areas of water consumption. To this end, 40,000–50,000 rainwater harvesting systems are installed yearly in Germany and most of these households use rainwater for their laundry. Some of the rainwater harvesting technologies that are being employed:

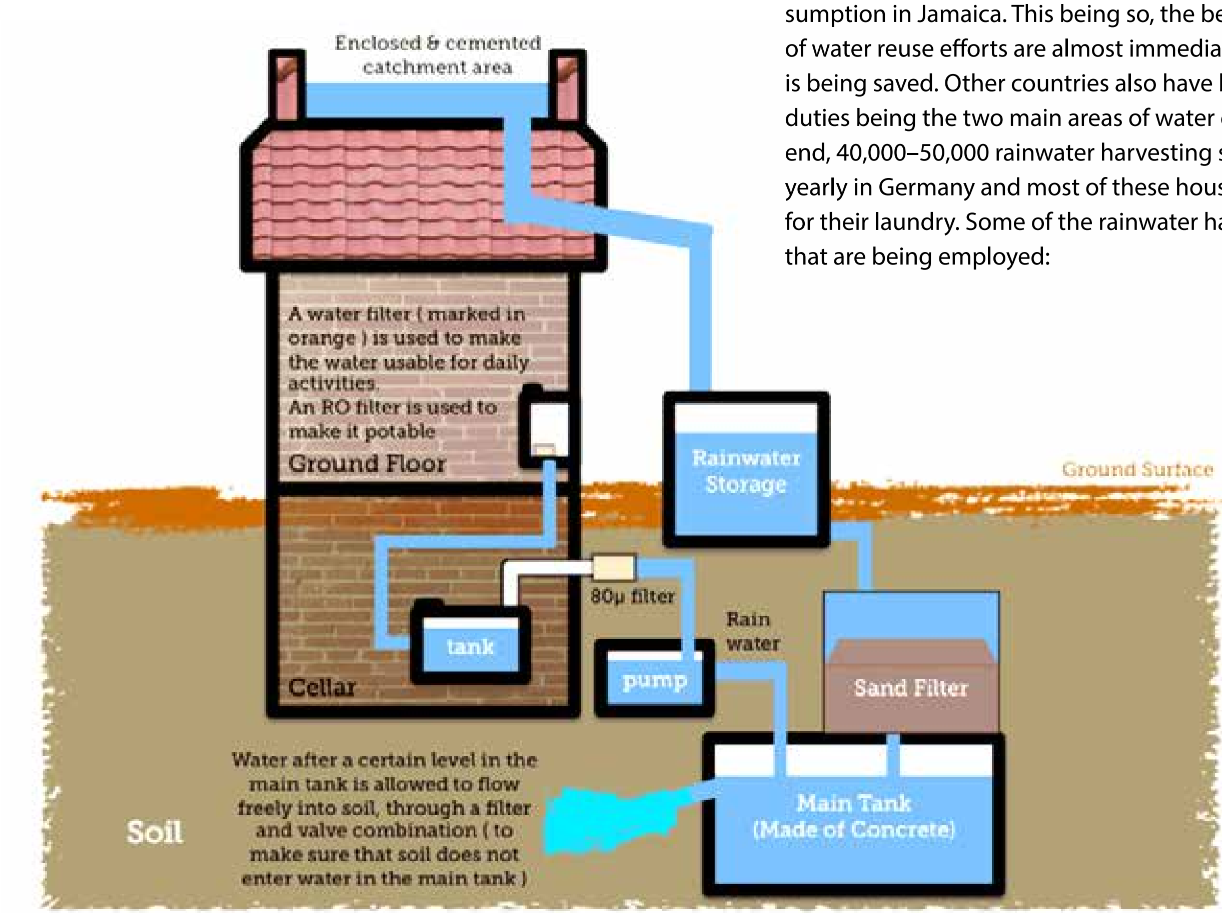


Figure 17 Dry System Rainwater Catchment. Retrieved from https://worldwaterreserve.com/rainwater-harvesting/introduction-to-rainwater-harvesting/

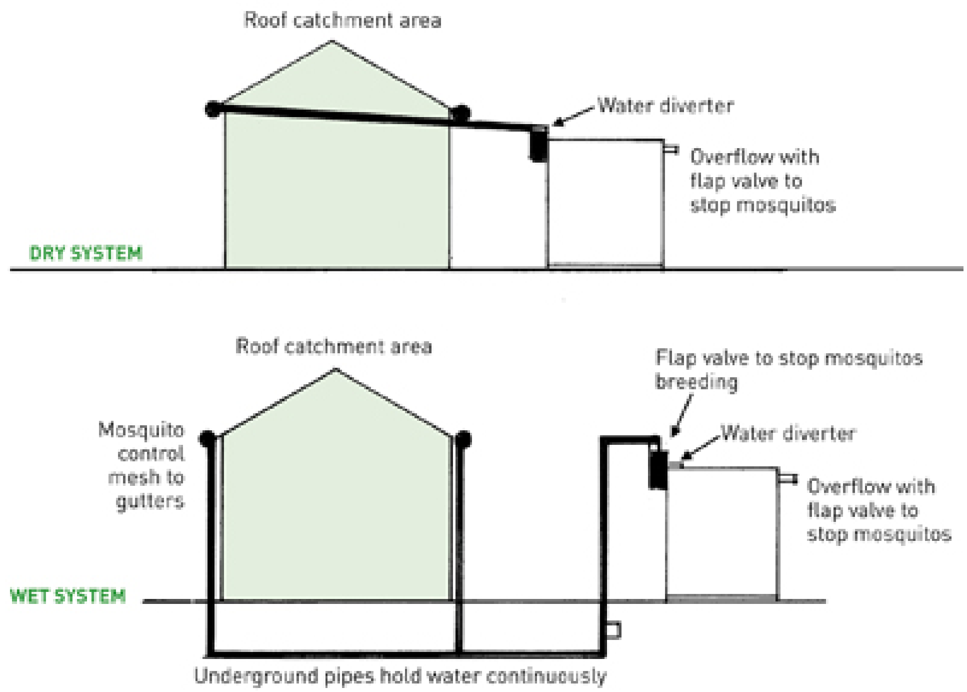


Figure 18 Wet System vs Dry System Catchment. Retrieved from https://tankulator.ata.org.au/siting-a-tank.php

The dry water catchment system channels water from the roof into tanks typically located some distance away from the house. The design of the tanks is represented in the figure above. It is called a dry system because all the water is emptied from the pipes into the catchment area, thus leaving the pipes dry. This particular method is favoured for its large storage capacity and the ability to prevent flooding by reducing surface water by sequestering excess water underground.

Unlike the dry system, the wet system has underground pipes that can be grounds for breeding mosquitoes if proper control mesh isn't installed on gutters. However, either method used requires some amount of water treatment. Water can be contaminated by microorganisms, chemicals, or debris. To avoid contamination by microorganisms and debris, ensure appropri- ate filters are used. Avoid copper or lead roof surfaces for harvesting to prevent any chemical contamination. To further treat water, other methods can be used such as chlorination, boiling and UV Light penetration for the killing of viruses and bacteria.

5.8.1 Jamaican Design Considerations

1. UNDERSTAND YOUR NEEDS:

The volume (quantity) and quality of rainwater needed must be clearly understood. As it relates to volume, each member of the typical water conservative Jamaican household requires 50 litres of water per day, per person for drinking, sanitation, bathing, cooking, kitchen use and non-potable uses. Rainwater harvesting systems can be designed to meet this need (potable and non-potable).

Non-potable water demand in homes includes toilet flushing, irrigation, and clothes/dishwashers and can represent up to 50% of the total water needs of individuals within the home. As it relates to water quality, the recommended key design considerations for rainwater harvesting systems are:

i. Jamaica's National Potable Water Standards – Interim Jamaican Criteria developed from WHO guidelines (potable water)

ii. Draft Jamaica National Ambient Water Quality Standard–Freshwater, 2009 (Non-potable water)

Household rainwater harvesting systems should be designed to meet either (i) or (ii) above, never both. The Ministry of Health and Wellness sets and monitors standards for potable water in Jamaica and their approval must be sought in the designing of any rainwater harvesting system for potable water provision.

2. UNDERSTAND YOUR ENVIRONMENT

- Vegetation
- Intruders
- Seasonality
- Fine particles
- Hidden activity

3. APPLY THE 8 RAIN HARVESTING STEPS

- Limit sources of contamination
- Plan for volume
- Filter leaves and debris
- Divert the first flush
- Secure the system
- Manage standing water
- Consider a safety net
- Monitor & Maintain

5.8.2 Installation

A typical rainwater harvesting system for a Jamaican home should have the following components:

- Assorted pipes and fittings (raw rainwater and treated rainwater piping and fittings)
- Catchment surface
- Guttering
- Downpipes or Downspout
- First flush and cleanout system
- Washout installation on existing storage tank
- Conveyance to storage tank
- Gutter screens/Pre-tank debris filtration and removal
- Storage tank
- Pump (optional)
- Post tank filtration and treatment
- Distribution system to end uses (gravity flow and/or pressurized flow)
- Post filtration equipment
- Chlorination equipment

5.8.3 Use & Maintenance

Below are some important maintenance tips for rainwater harvesting installation:

1. GUTTERS - MONTHLY

Check for rusting or leaks and use sandpaper and aluminium gloss paint to fix the rusting areas, and use silicon glue to repair leaks. Make sure gutters are secured to wooden flashings and wood is not rotting.

2. GUTTER SCREENS - MONTHLY

Check if damaged or clogged with leaves or dirt and clean or repair/replace.

3. FIRST FLUSH

After every rainstorm, clean by unscrewing end cap slowly, draining and remove debris collected. Screw end cap back on, but not all the way so as to allow for the pipes to drain slowly.

4. GRAVEL PITS- MONTHLY

Check and clear debris or garbage and if necessary add a fresh layer of sand to ensure that drainage can still occur.

5. TANK-ANNUALLY

Clean and disinfect tank to prevent slime, algae, bacterial growth, and the build up of sediments. To clean the tank:

- Drain all the water from the tank and close the tap. It is preferable to wait until the tank is almost empty (at the end of the dry season) to clean it.
- Wash and remove dirt from inside surfaces of the tank with water.
- Drain the wash water and sediment from the bottom of the tank by opening the spigot.
- Use chlorination to disinfect the inside surfaces of the tank. Chlorine tablets can be added to the tank, or add bleach (5ml of bleach per litre of water added) and mix it very well. Once the water inside the tank is chlorinated, let the chlorine solution sit in the tank for 3-5 hours, and then drain the tank completely.
- Fresh water can then be added to the tank. Run the water from the spigot until there is no smell of chlorine, and then continue normal usage of the tank.

5.8.4 Safety

The primary safety concerns associated with rainwater harvesting system installation, operation and maintenance relate to water tank/equipment siting and installation, use of heavy machinery, confined space entry, signage, and access prevention (human and vermin).

1. **Utilities:** All above-ground and below-ground utility lines (JPS, NWC, etc) serving the home must be properly located before beginning the rainwater harvesting system installation. Site designs should be adjusted where possible to avoid utilities and obstacles. Proper procedures for lockout/tagout for electrical connections, trenching and excavation, site control, should be adhered to. Jamaica's OSH Act (2017) can provide some guidance on these.

2. **Tank Siting and Installation (Buoyant Force):** Underground water storage tanks present a safety risk. Water buoys up objects immersed in it, therefore an underground water storage tank can be forced out of the ground by buoyant force if:

   i. Soil is saturated

   ii. Tank is empty

   iii. Tank lacks sufficient ballasting, strapping, and overfill to counteract the buoyant force

Calculating the buoyant force is the first step in determining how to design underground tank systems to ensure their stability and safety.

Buoyant Force (lbs) = V ft3 x 62.4 lbs/ft3

Buoyant force (lbs) = upward force exerted on underground tank when soil is saturated

V = volume of tank (ft3)

62.4 lbs/ft3 = buoyant force exerted per cubic foot of underground tank volume

The Buoyant Force calculation must always be done if the excavation for underground tanks cannot be drained to daylight by gravity.

3. **Confined Space Entry:** The insides of tanks above ground and underground are considered confined spaces, and during installation and maintenance of an RWH system, persons may be required to enter a water-storage tank. Appropriate training, safety equipment, and permits may be needed depending on the size of the system.

5.8.5 Cost

Estimates for a rainwater harvesting system for a typical Jamaican home (house size: 810 sq. ft. house, 2 bed-1bath) range between J$150,000 and J$250,000.

The major components are summarised below:

Item	Cost
PVC Guttering installation	$25,000
Metal Bars for screen	$12,000
Assorted PVC piping installation	$15,000
Chlorine treatment system	$75,000
1000 gallon plastic tank	$40,500
Assorted DN Piping	$10,000
Labour	$25,000
Materials Delivery	$4,000
TOTAL	$206,500

5.8.6 Possible Inconveniences for Householders

1. UNPREDICTABLE RAINFALL

It is very difficult to predict rainfall, and when it does rain, all places do not receive the same amounts. It is not advisable to depend solely on harvested rainfall to meet a household's needs in areas where rainfall is limited. It is suitable, however, to depend on rainwater harvesting alone in areas that receive plenty of rainfall.

2. INITIAL HIGH COST OF INSTALLATION

Because of the unpredictability of rainfall, it is very difficult to calculate the cost recovery period of a rainwater harvesting system. Also, the initial installation cost for the system will increase depending on the system's size and whether it is being designed for potable or non-potable use.

3. MAINTENANCE

Rainwater harvesting systems are prone to rodents, mosquitoes, algae growth, lizards, and insects, which contaminate supplies. If not regularly and properly maintained, they can become breeding grounds for many animals.

4. TYPES OF ROOFING

Certain types of roofs may seep chemicals, insects, dirt or animal droppings that can harm plants if used for watering.

5. STORAGE LIMITS

Storage is the biggest disadvantage of rainwater harvesting, and is directly proportional to installation and maintenance costs.

5.9 Greywater recycling systems: recovery and reuse

Since greywater is typically water that has already been used within the home, the main concern is contamination and bacterial growth. At one point, kitchen wastewater was once considered to be greywater, but convention has moved away from such definition and now considers greywater to be used, low-polluted water within the home, with the exception of kitchen water. Low-polluted wastewater includes that from bathtubs, showers, hand-washing basins and, sometimes, washing machines.

Greywater reuse thus far has been mainly concentrated in flushing and landscape irrigation. From an economic point of view, it would be advantageous if greywater recycling does not remain limited in this way, but it has been a challenge in forging habits in this area of water recycling.

Given that greywater is already polluted, treatment mechanisms must be maintained and standardised for the system to be efficient on a development scale. Cross-connections between the drinking water and the greywater networks are strictly excluded. Unlike cases in rainwater harvesting systems where cross-connection can occur with the use of a restrictive backflow system to prevent cross contamination, in the case of greywater systems, this is entirely advised against, so much so that the treated water is recommended to have its own plumbing system.

At the international level, there exist different quality requirements for recycled greywater dependent on the specific use, whether recycled greywater will be used for crop or landscape irrigation, or for toilet flushing. As such, any greywater system in Jamaica must adhere to our own quality requirements that can be found in our plumbing and building codes.

5.9.1 Design Considerations

Greywater or sullage is all wastewater generated in households or office buildings from streams without faecal contam- ination, i.e., all streams, except for the wastewater from toilets. Sources of greywater include sinks, showers, baths, washing machines, and dishwashers.

As greywater contains fewer pathogens than domestic waste-water, it is generally safer to handle and easier to treat and reuse onsite for toilet flushing, landscape or crop irrigation, and other non-potable uses.

Approval for a greywater disposal system must be obtained from the building official (Environmental Health Unit of the Ministry of Health) and the local authority.

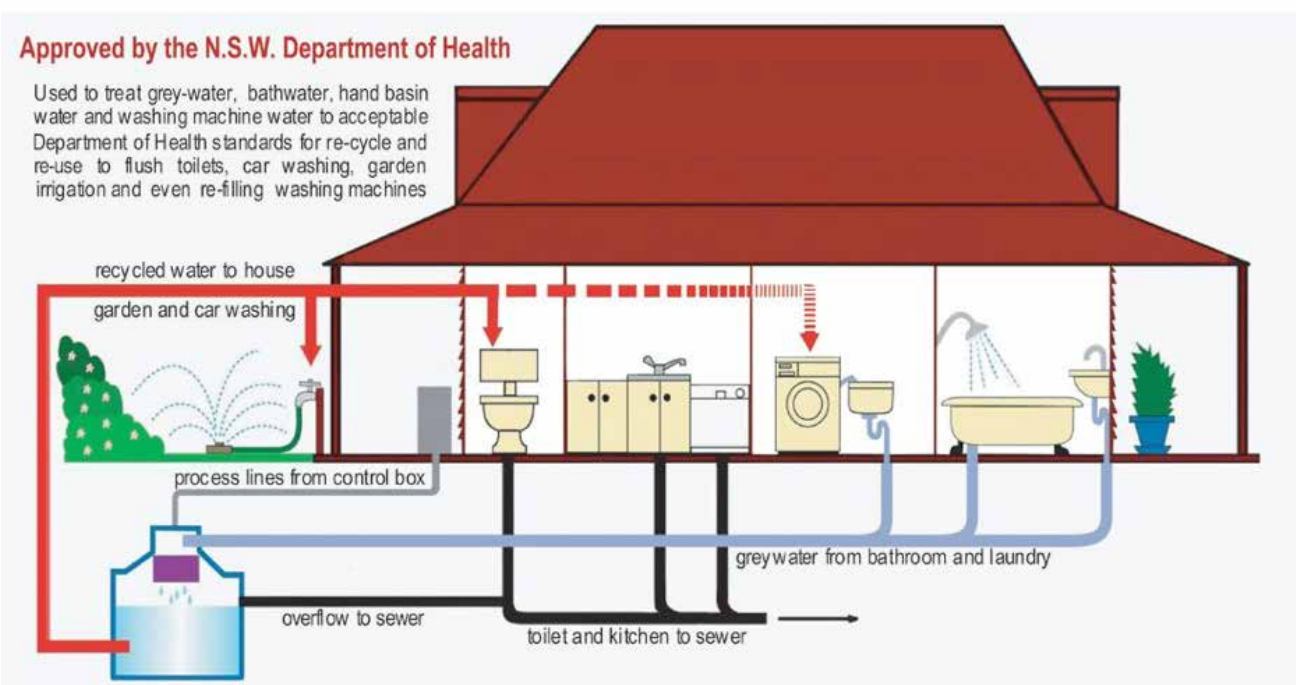


Figure 19: Greywater Plumbing System.

5.9.2 Installation

Laundry-to-landscape systems are the simplest and most accessible types of greywater reuse systems. Below are some basic steps and considerations to be followed in their installation.

STEP 1: ESTIMATE YOUR GREYWATER PRODUCTION BY ASKING THE FOLLOWING QUESTIONS:

- How many loads of laundry are done in a typical week?
- How many gallons of water are used per load?

STEP 2: DECIDE WHAT PLANTS TO IRRIGATE

- Plants with larger root zones do better with greywater irrigation.
- The plants stay happier and healthier with consistent laundry water patterns.

STEP 3: ESTIMATE PLANT IRRIGATION REQUIREMENTS

Does Your Greywater Production = Your Plant Irrigation Requirements? Pick the right amount of plants based on your greywater output. Irrigation requirements depend on whether the plants being irrigated are water-intensive (e.g., fruit trees) or drought-tolerant. Plants usually have an estimated water-demand factor that can be determined through online research or through contacting a local nursery.

STEP 4: PLAN THE PATH OF TRAVEL

Laundry-to-landscape systems have limitations that affect the greywater's path of travel through a landscape, including topography, number of distribution points (i.e., mulch basins), and piping placement. Importantly, these systems should not be installed at properties with high water tables.

STEP 5: INSTALLATION

A licensed plumber should be used to install:

- Three-way valve, which allows the user to direct greywater into either the existing sewer line or the new greywater-irrigation pipelines;
- Air vent/air admittance valve, which prevents formation of a vacuum within the new pipeline; and
- Proper 1" poly tubing and mulch-basin distribution points, which carry the greywater from the laundry to the root zones of plants within the landscape.

STEP 6: PRODUCT CHOICES

Avoid using products that can harm soils and plants. These products include but are not limited to:

- Salts or sodium compounds;
- Boron, borax, or borate;
- Peroxygen, petroleum distillate or alkyl benzene;
- Chlorine bleach (hydrogen peroxide bleach is okay); Water softeners that use sodium chloride (potassium chloride is okay); and antibacterial, which alter the biology of natural occurring bacteria in the ground and groundwater

5.9.3 Safety, Use & Maintenance

Each system must have its own Maintenance and Operations Manual, detailing the working parts, layout of system, and maintenance requirements. The 3-way valve must have a label directly above it, detailing the direction of flow. This manual must stay with the operational greywater system in the event that the homeowner(s) or tenant(s) cease to live at the property. Furthermore, the following steps must be adhered to:

- Do not eat plants or vegetables that have come in direct contact with greywater (e.g., root vegetables),
- Water used to clean soiled material (e.g., diapers, oily rags, etc.) must be diverted to the sewer using the three-way valve.
- Greywater must be diverted to the sewer during the rainy season, typically October 1 through April 1, to eliminate ponding or runoff.
- Do not store it - greywater must be diverted into the landscape or sewer immediately.

5.9.4 Cost

A simple greywater recycling system can be installed at minimal cost within a Jamaican household. Greywater from bathroom sink, shower and washing machine can be piped using PVC fittings, adapters and hoses, and used for the watering of plants and lawns. Typical costs for a simple system are:

Materials	Cost	Source
Elbows, PVC Pipe Fitting	$1,500	Jamaica Plumbing Supplies
Adapter	$500	Jamaica Plumbing Supplies
Hose	$2,020	Jamaica Plumbing Supplies
Total	**$4,020**	

5.10 Outdoor water saving technologies

1.1.1 DRIP IRRIGATION SYSTEMS

With housing developments using a considerable amount of water for landscaping purposes, drip irrigation would offset the quantity of water utilised for landscaping and even increase the efficiency by which household plants get water. The prospect of building a plumbing system supplied by greywater recycling would not only reduce issues with getting people to buy into greywater recycling, but also bolster the aesthetic appeal of properties by implementing a sustainable gardening system.

With drip systems being one of the more preferred methods of irrigation, technologies have been developed to encompass four main types of the system. There is the porous hose system that has holes along the entire hose structure and sweats water in the lawn areas where it is placed. Then there is the emitter drip that has evenly spaced holes typically around 15 inches apart and drips water into the soil. More advanced types such as the watermatic have micro-spray heads that minimise evaporation, thus conserving more water. Last, there are the micro misting sprinklers, which water roots evenly and help to keep the sur- rounding environment cool.

Figure 20 Types of Drip Systems – porous hose (left), drip emitter, watermatic spray, micro misting sprinklers (right)
Cost: One (1) acre drip irrigation kits costs approximately $34,000 excluding installation costs (Source: Isratech Jamaica Limited)

5.10.2 FILL CYCLE DIVERTER

These divert water from overflow tube to improve tank & bowl filling process and cut water wastage. On average, savings of 30% can be realized. Fill cycle diverters cost approximately J$200.

Figure 21: Fill Toilet Bowl Fill Cycle Diverter. Source: Amazon.com

5.10.3 GARDEN HOSE NOZZLE WITH AUTO SHUTOFF

Figure 22 Garden Hose Nozzle with auto shutoff.
Cost: J$1,200

5.10.4 GARDEN HOSE TIMER

Figure 24 Garden Hose Timer
Cost: J$2,200

[6]

CODE COMPLIANCE: NATIONAL BUILDING ACT (2019) AND JAMAICA NATIONAL BUILDING CODE

Jamaica's National Building Act took effect on January 19, 2019. A Jamaica National Building Code administers the act. As it relates to plumbing and water efficiency within Jamaica's urban housing sector, the National Building Code adopts the provisions of the International Residential Code (IRC) into a Jamaican Application Document titled the 'Jamaican Standard Small Building Code and Jamaica Application Document for the International Residential Code'.

The code speaks to "any one- and two-family dwelling (including townhouses) or small non-residential structure or part thereof, that is used, or designed or intended for human occupation, for living, sleeping, cooking, eating, recreation, working, and any combination thereof and shall include accessory structures thereto".

Published by the Bureau of Standards in 2017, the national residential code enables engineers to design fully functional family dwellings with the following broad specifications:

1. One-family detached dwellings
2. Two-family detached dwellings
3. Multiple single-family dwellings (town houses) of not more than three storeys
4. Small and simple non-residential buildings of no more than two storeys that will always have fewer than 15 persons at any given time

Though energy efficiency and conservation is specifically referenced within Jamaica's residential code (Chapter 13), no mention is made of water efficiency or water conservation. This represents a significant gap in the country's efforts at climate adaptation. Jamaica now needs a residential green building code that encompasses the four pillars of sustainability within building construction:

i. energy efficiency and conservation
ii. water efficiency and conservation
iii. renewable energy use
iv. environmental design

This guideline document supports sustainable development within Jamaica, but needs an effected residential green building code to truly be effective.

[7]

SUMMARY: BASIC COST GUIDE TO CONSTRUCTING/ RETROFITTING A WATER EFFICIENT HOME

Water Efficient Technology	Implementation costs: New Construction ($)	Implementation Costs: Retrofit ($)	Qty	Total: New Construction ($)	Total: Retrofit ($)
1. Water efficient toilets	45,000	55,000	1	45,000	55,000
2. Water efficient shower heads	2,100	2,100	1	2,100	2,100
3. Water efficient bathroom faucets	13,700	15,500	1	13,700	15,500
4. Bathroom low flow aerators	400	400	2	800	800
5. Water efficient kitchen faucets	8,500	8,500	1	8,500	8,500
6. Kitchen low flow aerators	650	650	1	650	650
7. Water efficient washing machines	75,000	80,000	1	75,000	80,000
8. Water efficient dish washers	75,000	75,000	1	75,000	75,000
9. Leak detection technology	N/A	N/A		N/A	N/A
10. Rainwater harvesting systems (2,000 gallon storage)	130,000	130,000	1	130,000	130,000
11. Grey water recycling system	4,020	4,020	1	4,020	4,020
12. Drip irrigation systems (0.25 acre)	44,000	44,000	1	44,000	44,000
13. Fill cycle diverters	500	500	1	500	500
14. Garden hose nozzle with auto shutoff	1,200	1,200	2	2,400	2,400
15. Garden hose timer	2,190	2,190	2	4,380	4,380
TOTAL				**$406,050**	**$422,850**

[8]

RECOMMENDATIONS

1 Have more Private-Public partnerships like this that brings more of the Government climate adaptation policy positions into the developmental marketplace outlined in the Jamaica Vision 2030 national development plan.

2 Develop a "Jamaican Residential Green Building Code". The current residential building code does not account for policy positions outlined the National Water Sector Development Plan or the Jamaica Climate Change policy. As such, it is recommended that the development of a National Residential Green Building Code be fast-tracked. This code would outline the standards to be adhered to locally for the construction and retrofitting of all family dwellings as it relates to water-use efficiency, rainwater harvesting, and green building design.

3 There is urgent need for the finalization of a Jamaican National standard for potable water as the Interim Jamaica Drinking Water Standard (I-JAM) of 1982 was never entrenched in any law or regulation. A national framework and standards for potable water needs promulgation. Following this, national common design criteria for the production of potable water from rainwater harvesting systems can be developed for inclusion within a Jamaican Residential Green Building Code. This is especially important for households not connected to the National Water Commission grid.

4 Make it mandatory for large housing scheme developments to have leak detection systems in place.

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NOTES

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PPCR PILOT PROGRAM FOR CLIMATE RESILIENCE

CIF CLIMATE INVESTMENT FUNDS