PRELIMINARY PROJECT PLAN
FOR A RAINWATER HARVESTING SYSTEM FOR THE STADE OLYMPIQUE DE SOUSSE (TUNISIA)

Col·laboració de BCASA amb la Direcció de Relacions Internacionals i Cooperació de l’Ajuntament de Barcelona en les iniciatives

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PRELIMINARY PROJECT (CONCEPTUAL DESIGN)

PRELIMINARY PROJECT PLAN FOR A RAINWATER HARVESTING SYSTEM FOR THE COMPLEXE DE L’ÉTOILE DU SAHEL (TUNISIA)

MUNICIPALITY OF SOUSSE

MEDCITIES - URBAN SUSTAINABLE DEVELOPMENT STRATEGIES

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1. PROJECT BRIEF

The present project is a preliminary assessment for the design and construction of a Rainwater Harvesting System (RWH) for the Complexe de L’Étoile du Sahel in the city of Sousse in Tunisia.

Rainwater harvesting is the collection of rainwater directly from the surface(s) it falls on. This water would otherwise have gone directly into the drainage system or been lost through evaporation and transpiration. Once collected and stored it can be used for non-potable purposes. Rainwater harvesting is a water conservation measure specially useful in regions where other water resources are scarce or difficult to access. This strategy can play an important role in future management of water resources in Sousse and can represent a possible solution to address water stress in the city. Rainwater source control can also represent an opportunity of savings in energy use and related emissions, relative to the reduction in mains water demand (and wastewater to be treated).

Water resources are under pressure, a high volume of water is taken from the environment for human use. Demand for water is rising because the population is increasing, lifestyles are changing and the impacts of a changing climate are becoming clearer. In arid climates where large numbers of people live and work, water is scarcer and demand is normally higher.

Any RWH system will reduce the dependence on the mains water supply. Potential savings need to be assessed on an individual basis before any system is implemented. Reducing the volume of mains water supplied means less water is taken from lakes, rivers and aquifers and more is left to benefit ecosystems and help sustain the water environment.

RWH systems can also reduce the risk of flooding and pollution as less rainwater is discharged to drains and sewers and, ultimately, to rivers. They can contribute to slowing down the flow of water and reduce the pressure on drainage systems in times of high flow. Sustainable drainage systems (SUDS) often incorporate rainwater harvesting. SUDS reduce the risk of flooding by increasing the retention and control of surface/storm-water.

1.1 BACKGROUND

The project is framed under MedCities, a network of Mediterranean coastal cities created in Barcelona in November 1991, and in concrete under the USUDS project for the elaboration of urban sustainable development strategies in the Mediterranean.
The USUDS project, co-financed by the ENPI-CBCMED programme of the European Union, the Spanish Agency of International Cooperation for Development, the Provincial Council of Barcelona, the Municipality of Barcelona and the Hariri Foundation for Sustainable Human Development, has as an overall objective to promote sustainable development and social cohesion in Mediterranean Cities and as specific aims:
- to focus on the creation of three new Urban Development Strategies in the cities of Sousse (Tunisia), Saida (Lebanon) and Larnaka (Cyprus) and
- to promote a network of cities interested in building and implementing urban sustainable development strategies.

In order to promote the short-term implementation of projects identified by the urban development strategies elaborated under USUDS, some technical assistance missions have been organised to these cities with the participation of associate partners of the project. Under this initiative BARCELONA CICLE DE L’AIGUA transfers knowledge and experience to the Municipality of Sousse and other public institutions in charge of the water cycle management of the city, such as the ONAS-Office National d'Assainissement and the SONEDE-Société Nationale d'Exploitation et de Distribution des Eaux.

This project presents a preliminary report to implement a sustainable urban strategy for water management in the area surrounding the Olympic Stadium of the city.

1.2 SCOPE

The design of a rainwater harvesting system requires specific sizing due its complexity and the technical aspects involved. When designing a reliable, efficient rainwater harvesting system a wide range of criteria needs to be taken into account. All the information provided in this document is preliminary, all plans, specifications, assumptions and requirements of a RWH system will need further study and review. Furthermore client's requirements, site restrictions have not been considered and will need to be addressed in the future by the designer to provide a project specific 'detailed approach'.

The scope of the present document and its aims are as follows:

- Make a preliminary assessment on the potential use of RWH techniques in the Complexe de L’Étoile du Sahel area.
- General description of a RWH system and its main components, including sizing of components of the RWH and preliminary budget.
PRELIMINARY PROJECT PLAN FOR A RAINWATER HARVESTING COMPLEXE DE L’ÉTOILE DU SAHEL

- Site feasibility and scoping assessments, covering a range of engineering, environmental and sustainability constraints.

- Identify next steps, information and actions needed to develop a construction project for the RWH System.

1.3 OUTCOMES / EXPECTED BENEFITS

- Preliminary plans, specifications and budget for a RWH system in the Complexes de L’Étoile du Sahel area.

- Promote conservation of water, rainwater harvesting promotes self-sufficiency and appreciation for water as a resource. It also promotes water conservation, while providing an alternative water source.

- Energy conservation through optimization of stormwater management, the centralized water system is bypassed through the use of rainwater harvesting, this system will conserve energy.

- Reduce undesired stormwater runoff, local erosion and flooding from impervious cover associated with buildings is lessened as a portion of the local rainfall is diverted into collection tanks, leaving less stormwater to manage.

- Promote making the most efficient use of the city’s resources, not wasting water and taking advantage of alternative water sources

1.4 PRELIMINARY ASSUMPTIONS

Each rainwater harvesting system is unique and should be evaluated separately. Proper sizing is important when designing a RWH system. The quantity of rainwater available for collection, water uses, space available, local regulations among other will determine the right sizing of the system that will affect the installation cost, operation, and on-going maintenance. In this project

1. Total annual rainfall of 327, 1 mm and catchment area of 27,000 m² (basin 3 and 4) with a runoff mean coefficient of 0.9.


3. Monthly precipitation quantities evenly distributed during the weeks.
4. Water quality flow rate (WQF-flow that will treat the up to 90th cumulative percentile volume of the annual runoff) is 108 l/s, based on the rational method applying an intensity of 18 mm/h. Intensity established comparing IDF curves and intensity distribution curves obtained for Sousse on the web.

5. Only catchments are intercepted and used for stormwater harvesting. The runoff coefficient applied to these areas for sizing of the cistern is 0.8.

6. Reference evapotranspiration calculated according to FAO-56 PM method Hargreaves using limited climatic data available on the internet.

7. Irrigation needs based on a 16000 m² surface of grass soccer fields and the reference evapotranspiration for the city of Sousse.

8. Pollutant concentration data for Total Suspended Solids, Total Phosphorous, Total Nitrogen and Heavy Metals determined using Schueler’s Simple Method (used for assessing and comparing stormflow pollutant loadings moving from the catchment). The simple method provides a general planning estimate of likely storm pollutant export from areas at the scale of a development site, catchment or subwatershed. More sophisticated modelling may be needed to analyze the watershed if no monitoring data is available.

9. Fecal coliform median urban runoff concentration of 20,000 ufc/100 ml (derived from NURP data). Fecal coliform is more difficult to characterize than other pollutants. Data are extremely variable, even during repeated sampling at a single location. Because of this variability, it is difficult to establish different concentrations for each land use.

10. Water reclamation and reuse standards based on international standards.
2. RAIN WATER HARVESTING SYSTEM COMPONENTS

The RWH System will capture runoff from roofs or other suitable surfaces (e.g., terraces, walkways, grassed areas and with proper pre-treatment, parking lots), provide water quality treatment, and use pumps or sufficient head to supply water to a distribution system.

Rainwater systems come in all shapes and sizes, from simple catchment system under a downspout to large above and/or underground cisterns with complex filtration systems that can store thousands of gallons of water. Most rainwater collection systems for hard surfaces need to consider all the components described below.

2.1 THE CATCHMENT

Surface runoff will be captured from the existing conveyance system designed to intercept the rainwater from the Complexe de L’Étoile Du Sahel in Sousse, Tunisia (Fig.2). The Catchment selected includes driveways, parking areas, etc. and can be suitable for rainwater harvesting but needs to take into consideration higher risks of water pollution and requires more treatment. When possible rainwater at a roof level should be considered as a harvesting surface in order to minimize the levels of treatment needed.
Fig. 2. Top view of the complex L’Étoile Du Sahel in Tunisia, Sousse. Considered catchments for rainwater harvesting are situated at the right side of the soccer field.

Nonetheless Hardscape Surfaces tend to be more contaminated than rooftops but contribute a large area in lower-density developments like the one studied. Walkways, parking lots, and roadways from the sports complex may lend themselves to harvesting if appropriate treatment is paired with suitable water usage applications.

Table 1. Water Quality Flow Rates calculated for the contributing catchments.

<table>
<thead>
<tr>
<th>CATCHMENT ID</th>
<th>CATCHMENT Area (Ha)</th>
<th>Land Use</th>
<th>Slope (m/m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>1,6</td>
<td>Residential</td>
<td>0.4855</td>
</tr>
<tr>
<td>4</td>
<td>1,10</td>
<td>Commercial</td>
<td>0.0095</td>
</tr>
</tbody>
</table>

The size of the catchment areas selected is shown in table 2 and will determine how much rainwater can be harvested. The areas for the different catchments have been taken from the hydraulic calculation available for the stadium.

The catchment area has a significant impact on both the design and water savings potential of RWH systems. In general, it is recommended that the size of the catchment area used for a RWH system be as large as possible to maximize water savings. For most RWH systems collecting rainwater from hard surfaces, the size of the catchment area is usually limited by the peak flows and the levels of treatment needed.
2.2 CISTERN

Cisterns are available in all shapes and sizes, but there are basic attributes that should be present in every cistern no matter what type is selected (see Figure 3). The most common elements to specify include the following:

- **Watertight rating** — Vessels designed to hold water should be able to maintain a minimal watertight rating for the life of the cistern. Since almost all systems are open to the atmosphere, this is usually passive head pressure equal to the depth. In most cases, it is only a few pounds per square inch (psi). Tall, aboveground cisterns are the exception where 10-15 psi may be more common. Testing to ensure the watertight rating can be difficult for large systems, so a factory test or production standard may be the best specification requirements to ensure water tightness of the delivered system.

![Diagram of cistern components](image)

**Fig. 3.** Cistern details and main components that the RWH system for Sousse needs to consider.

- **Code requirements** — Many international codes require two important elements in a cistern that are designed to improve water quality. The first is a *calming inlet*, which creates full pipe flow within the inlet pipe and discharges influent water upward from the bottom of the cistern. This reduces turbulence and the potential for disturbing solids that have settled on the bottom of the cistern. The second common requirement is a *floating outlet*. The intake hose to the pump should be flexible with an attached inlet screen to block gross pollutants. The hose should be connected to a float so that the intake is never at the very bottom of the tank where solids could be sucked into the pump. It should also never be at the surface where fine floating materials may be present. The float...
should be suspended within the water column, ensuring the cleanest water within the cistern is extracted. This improves the quality of the re-use water. Cisterns should also have an overflow path, vents and screens or water traps over the inlets and outlets to prevent access by insects and animals.

- **Pump types and location** — There are many options to configure pumps. Submersible pumps placed directly in the cistern or in a downstream wet well are powerful options for applications with higher head, but must be hard wired with power into the cistern. Suction pumps placed aboveground are also common, but are limited by depth and pressure. In many cases, a low-pressure transfer suction pump is connected to the cistern with an additional pressure booster pump in the mechanical system.

- **Access and maintenance** — RWH systems may have a design life of 20 to 50 years or even longer. Even though all systems should include pretreatment, sediment will collect over the years as millions of gallons of water pass through a commercial-sized system. All cisterns should be designed with multiple access points to support pump maintenance, inspection, repair, and cleaning.

### Material Choices

There are a wide variety of cistern materials to choose from (see Table 2). Because they are often smaller in size, residential systems offer more options, but not all will scale to tens of thousands of cubic meters in a cost-effective manner. The RWH considered focuses on commercial and institutional-scale applications where storage requirements are big. The following material should be considered for the construction of the tank:

- **Fibreglass tanks** are a common choice for RWH tanks because they offer high pressure ratings and resist corrosion. They are mostly used belowground and can be sized up to 1000 m³ and 4 meters in diameter. While long lasting, they are often not the most economical choice and require special care during handling and installation. Because they are built as continuous tanks, the large sizes require over-sized shipping loads that increase overall costs. Multiple tanks are required for large systems.

- **Steel Reinforced Polyethylene (SRPE) cisterns** are newer to the market and combine the longevity of polyethylene and the strength of steel in an efficient and economical package. These tanks resist corrosion and can last longer than 75 years. Sections are manufactured as long as 15 meters and multiple sections can be combined and fused together in the field to create one large, leak-proof cistern sealed to a 15 psi rating. SRPE is easily patched in the field if damaged and can handle burial as deep as 8 meters. For cisterns larger than 300 m³, they can also be the lowest cost option (see Figure 4).

- **Plastic crates** were once used solely for infiltration, but with a waterproof liner, they are also an entry level cistern option. The liner is installed prior to the crates (see Figure 5). Because liners can be prone to damage and installation errors, they often have a much shorter lifespan than other cistern options. They are an economical solution for sites requiring large storage volumes because they do not require heavy equipment for installation. More economical crates are typically not strong enough for more than 2 meter of cover, so increased
cover will increase cost. There is no maintenance access, so the design life for these systems could be less than 20 years.

**Table 2.** Comparison between different cistern materials available for rainwater harvesting.

<table>
<thead>
<tr>
<th>Material</th>
<th>Cost</th>
<th>Installation</th>
<th>Longevity</th>
<th>Durability</th>
<th>Maintenance Access</th>
<th>Best Use Capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fiberglass</td>
<td>$$$$</td>
<td>e</td>
<td>o</td>
<td>o</td>
<td>o</td>
<td>5,000 to 30,000</td>
</tr>
<tr>
<td>Polyethylene</td>
<td>$</td>
<td>e</td>
<td>o</td>
<td>o</td>
<td>o</td>
<td>&lt; 5,000</td>
</tr>
<tr>
<td>Steel Reinforced Polyethylene</td>
<td>$$$</td>
<td>e</td>
<td>o</td>
<td>o</td>
<td>o</td>
<td>10,000 to 100,000</td>
</tr>
<tr>
<td>Plastic Cisterns</td>
<td>$$$</td>
<td>e</td>
<td>o</td>
<td>o</td>
<td>o</td>
<td>5,000 to 50,000</td>
</tr>
<tr>
<td>Concrete</td>
<td>$$$$</td>
<td>e</td>
<td>o</td>
<td>o</td>
<td>o</td>
<td>30,000 (with high loading)</td>
</tr>
<tr>
<td>Waterproof Corrugated Metal</td>
<td>$</td>
<td>e</td>
<td>o</td>
<td>o</td>
<td>o</td>
<td>5,000 to 30,000</td>
</tr>
<tr>
<td>Monolithic</td>
<td>$$$</td>
<td>e</td>
<td>o</td>
<td>o</td>
<td>o</td>
<td>Up to 20,000</td>
</tr>
<tr>
<td>Plate Assembled On-Site</td>
<td>$$$</td>
<td>e</td>
<td>o</td>
<td>o</td>
<td>o</td>
<td>15,000</td>
</tr>
</tbody>
</table>

*During transport, staging and installation.

- Concrete structures can also be used as cisterns. They can be precast for faster installation or cast-in-place to suite specific site constraints. To achieve a watertight system, special care must be used to seal joints, and the engineer should require a coating appropriate for re-use applications because people and the environment will come in contact with the water. Concrete can develop leaks over time from cracks, and — in most cases — will need to be drained to seal the leak. For small- to medium size systems, concrete can be a more expensive option. But for very large systems, concrete structures may offer a better economic value and are worth consideration where the cistern will be under high loads.

**Fig. 4.** An underground SRPE cistern installation for rainwater harvesting, 50 percent backfilled with stone.
**Rain Water Harvesting System Components**

- Waterproof corrugated metal cisterns are another newer option for water storage. Thin gage steel with an aluminium alloy coating offers a cost-effective system, and can have a design life greater than 75 years in many conditions. These lightweight tanks can be built in diameters up to 4 m and up to 10 m long. The specific design should require testing documentation from a reputable supplier before specification. For small- and medium-size systems, these are the most economical option in most situations.

![Fig. 5. An underground plastic crate cistern with gravel backfill and impervious liner.](image)

**Design Considerations**

Sizing of the tank or cistern is best done with a continuous daily simulation model that calculates runoff captured, overflow and runoff released, domestic water savings, and required makeup water. Design life is an important design consideration and different material types offer a wide range of life expectancy. Similar to detention systems, it is imperative to select a material that will last in the local conditions for the life of the project, which can be many decades.

Unlike detention systems where the primary concern is the structural integrity, cisterns must also remain watertight during their life. For example, systems depending on liners may have a significantly shorter design life because they may be prone to leakage and cannot be repaired. While underground metal cisterns can have a design life of more than 50 years in many situations, some sites have soils that can be corrosive to metals. Other materials such as Steel Reinforced Polyethylene (SRPE) may be better suited for these situations. Ultimately, the best solution is dependent on the desired design life and the local soil conditions.

Structural capacity is a crucial factor when selecting a cistern. For commercial-scale systems, cisterns can be large, like detention systems, and many times the obvious choice is to install beneath a parking lot. Some of the smaller, entry level cisterns have limited loading capacity, so it may be better to locate them in a green space. For project sites that experience seasonal high groundwater, the cistern manufacturer
should supply buoyancy calculations. Most cisterns can be equipped with anti-buoyancy devices that prevent floating. Cisterns built from crates should be avoided in this situation because they cannot be strapped down effectively.

Installation and handling can be an overlooked design factor when choosing a cistern. Many materials — such as fibreglass — require stone backfill and are not strong enough to be backfilled with native soil. For large systems, these costs can add up.

For other materials such as SRPE, depending on the quality of the native soil, it may be possible to use a competent native material as backfill for the cistern. Using local materials as backfill can save the cost of exporting excavated soils and importing expensive stone. In addition, some materials must be handled with care and have a low impact resistance; bumps and dings sustained during unloading and installation can be costly to repair and upset project schedules.

2.3 ADVANCE RUNOFF TREATMENT SYSTEM

Advance treatment of the runoff involves settling and filtration processes to clean water prior to storage and provides several benefits. It protects downstream pumps, filters, and fixtures from damage or clogging, and lowers cleaning and maintenance costs by keeping pollutants out of the cistern and filters. It also reduces the amount of organic matter and biological oxygen demand (BOD) in the cistern, decreasing the likelihood of creating anaerobic conditions and associated odours.

When rooftop surfaces are used first flush diversion is required to meet some building codes and is based on the assumption that runoff from the beginning of a rainfall carries more pollutants. Many of these diversion structures are built into the downspout system and are sized to divert a site specific volume.

Table 3. General minimum water quality guidelines and treatment options for storm water reuse.

<table>
<thead>
<tr>
<th>Use</th>
<th>Minimum Water Quality Guidelines</th>
<th>Suggested Treatment Options</th>
</tr>
</thead>
<tbody>
<tr>
<td>Potable indoor uses</td>
<td>• Total coliforms – 0</td>
<td>• Pre-filtration – first flush diverter</td>
</tr>
<tr>
<td></td>
<td>• Fecal coliforms – 0</td>
<td>• Cartridge filtration – 3 micron</td>
</tr>
<tr>
<td></td>
<td>• Protozoan cysts – 0</td>
<td>sediment filter followed by 3 micron</td>
</tr>
<tr>
<td></td>
<td>• Viruses – 0</td>
<td>activated carbon filter</td>
</tr>
<tr>
<td></td>
<td>• Turbidity &lt; 1 NTU</td>
<td>• Disinfection – chlorine residual of 0.2</td>
</tr>
<tr>
<td>Non-potable indoor uses</td>
<td>• Total coliforms &lt; 500 cfu per</td>
<td>ppm or UV disinfection</td>
</tr>
<tr>
<td></td>
<td>100 mL</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Fecal coliforms &lt; 100 cfu per</td>
<td></td>
</tr>
<tr>
<td></td>
<td>100 mL</td>
<td></td>
</tr>
<tr>
<td>Outdoor uses</td>
<td>N/A</td>
<td>• Pre-filtration – first flush diverter</td>
</tr>
</tbody>
</table>

*cfu – colony forming units
*NTU – nephelometric turbidity units

Pretreating stormwater prior to storage protects downstream pumps, filters and fixtures from damage or clogging, and lowers cleaning and maintenance costs by keeping pollutants out of the cistern and mechanical system. It also reduces the amount of organic matter and biological oxygen demand (BOD) in the cistern, decreasing the likelihood of creating anaerobic conditions and associated odours.
For large scale applications like the one considered there a wide range of manufactured BMPs that can provide higher levels of treatment. A minimum of two levels of treatment will be required, settling and filtration, two systems used as pretreatment options in large scale commercial projects are described below.

Hydrodinamic Separators - Downstream Defender®

The Downstream Defender® is an advanced hydrodynamic vortex separator for the effective and reliable removal of fine particles along with oils and other floatable debris from surface water runoff. Its innovative design delivers high efficiency across a wide range of flows in a much smaller footprint than conventional or other swirl-type devices and is the perfect choice for any catchment likely to convey high quantities of contamination. The Downstream Defender® delivers a long stable flow path to maximise pollutant capture from surface runoff.

The device is able to tackle an assortment of pollutants including gross debris, litter, hydrocarbons, coarse sediments, fine sediments and particulate organics. In the field, pollution captured by the Downstream Defender® has been shown to be as fine as the pollutants captured in much larger settling ponds.

Contaminated surface water runoff entering the chamber is directed downwards and around the periphery of the chamber. Oils, litter and other floatable material is initially captured at the inlet and transferred to the oil storage zone as flows increase. The oil storage zone is protected from the treatment flow path and so prevents captured floatable material from wash out during peak flows.

Fig. 6. Advanced hydrodynamic vortex separator Downstream Defender for the treatment of stormwater.
As the flow continues to spiral around the periphery of the chamber, low energy vortex motion directs settleable solids into the base of the unit. The internal components isolate the base of the chamber from the treatment flow path preventing wash out of captured solids.

The treated water exits the chamber via the orientated outlet pipe after ensuring the longest possible retention time within the unit. Excess flows by-pass the vortex treatment chamber and also both the sediment and oil storage zones. These excess flows pass forward untreated via the orientated outlet pipe.

Applications:

- Removal of sediment and TSS
- 100% capture of floatable trash
- Removal of oils and grease from stormwater runoff (meets Class II Oil Collector requirements)
- Stormwater treatment for new developments and redevelopment projects
- Stormwater treatment Municipal/ DOT expansions or improvements for streets, roadways and parking lots
- Pretreatment for infiltration, stormwater detention and stormwater filtration

The Downstream Defender® has proven ability to prevent washout of captured pollutants. Carefully designed internal components isolate the pollution storage areas ensuring what is captured is retained, even during, even during peak storm events.

Passive Filtration – Upflo Filter®

The Up-Flo® Filter is an efficient high-rate stormwater filtration technology available for the removal of trash, sediments, nutrients, metals and hydrocarbons from stormwater runoff. As the industry’s only fluidized bed upflow filtration technology, the Up-Flo® Filter provides a higher level of treatment, a higher rate of filtration, longer life of filter media and a longer maintenance cycle than other filter systems.

The treatment processes of the units include sedimentation, flotation, screening, Inert filtration and reactive filtration. Contaminated surface water runoff enters the chamber via an inlet pipe or inlet grate and is directed between the filter modules to the sump of the chamber. Gross debris and sediment settle out in the sump, while oil and floatables rise to the surface of the water.

As water fills the chamber, the flow is directed up through the angled screen preventing larger material from reaching the filter media. Flow distributing media spreads the flow evenly across the filter media as the water level increases within the chamber. Treated water enters a conveyance channel at the top of the filter module, where it is directed to the outlet module and passes forward to the outlet pipe.

Applications and benefits:

- Sediment, hydrocarbon and nutrient control
- Heavy metals control
- Post-construction stormwater BMP for new developments
- Removing particles from Industrial runoff
- Source control at entry points to the drainage system
- Wetlands protection
- Rain water harvesting

Fig. 7. UpFlo® passive filtration system that provides sedimentation, screening and filtration of storm water on a low footprint.

Excess flows associated with extreme storm events are discharged directly to the outlet module via a syphonic bypass, which incorporates a floatables baffle to prevent the discharge of oils and floatable material. Following the storm event, water drains out of the chamber through the patented drain down port. This backwashes the filter media and leaves it dry between storm events, preventing pollutant leaching and media degradation.

All selected BMPs to treat runoff for a commercial RWH system should have a proven Track Record with regulatory agencies around the world and adequate and sufficient third party independent testing in the field and lab.

2.4 DISINFECTION SYSTEM

Many codes state that the inclusion of UV or chemical treatment might be beneficial in situations where there is potential for increased human exposure. Water quality and its impact on human health is a primary concern with rainwater harvesting. This issue is comprised of two components: end use of the rainwater and treatment provided.

Rainwater used for residential irrigation does not typically require treatment. Commercial applications and non-potable indoor uses require treatment but the type of use will determine the extent of treatment. Each application needs to assess and evaluate the level of treatment with which it is comfortable, but limiting rainwater reuse to water closets, urinals and hose bibs presents little human health risk. Each system will require some level of screening and filtration to prevent particles and debris from travelling through the plumbing system, and most standards and codes require
disinfection with UV or chlorination because of bacterial concerns. For the present project UV radiation is considered the most suitable for the uses considered for the harvested water.

UV radiation is common, affordable, and provides a high level of effectiveness (99.9 percent or better kill rate of pathogens). Typically, it is applied just prior to delivery as the last treatment step. One drawback is it does not provide any residual disinfection capability. Over time, the few remaining pathogens can reproduce and contaminate the water downstream. UV is best used for applications where the water will be used immediately, such as irrigation.

Construction of a UV disinfection inside the cistern has been considered at the preliminary stage. The main components are pipes for the water flow, quartz tubes, and UV light bulbs. Although the availability and prices of lamps and quartz sleeves in Sousse are fairly unknown. If UV bulbs are difficult to locate in the country. Scarce supply is a large concern for the sustainability of this option.

2.5 PUMPS, PLUMB AND CONTROL UNITS

For the system design, the pump used for RWH will need to both pull water out of the buried tank and create the pressure necessary for its intended use. Properly sizing the pump for an automatic irrigation system requires detailed knowledge of where the water is stored, pump location and intended use of the water. These issues will need to be addressed on the detailed design project when all the information required is available.
Submersible pumps, suction or jet pumps are common in rainwater harvesting systems. They are often used in conjunction with a pressure tank and switch for pump control. A floating pump intake equipped with a filter is recommended to withdraw water a few inches below the water surface.

Pumps are sized to meet the maximum instantaneous demand for all combined applications. They also provide standard city water pressure to meet code and operational standards. Duplex or even triplex pumps are common to ensure water service is not interrupted. Pump manufacturer or vendor should be consulted to determine which accessories are needed for specific pumps, the following devices should be included:

- Pressure tank—stores pressurized water to prevent the pump from cycling on and off to meet demand and supply a constant pressure.
- Pressure switch—engages the pump when a pressure drop is observed and disengages it when there is no demand.
- Check valve—prevents water from flowing back through the pump when it is not running.
- Float level switch—disengages the pump when water falls below a predetermined level.
- Throttling valve—controls the flow and pressure of water exiting the pump and is typically in the form of a gate valve.

Delivery systems commonly include pipes connected to an irrigation system and pipes that can be used to drain the cistern for cleaning or for protection from freezing temperatures. Drain pipes should be directed to a rain garden or to another location in the landscape. Hose bibs may be installed on the tank so that a hose can be connected for outdoor water use.

![Fig. 9. Delivery system and piping connecting the storage volume and the irrigation system.](image-url)
The primary considerations in planning the distribution system are construction and layout. The construction of the distribution network will mostly consist of a great deal of digging. The layout of the network could also potentially change a great deal on site from issues that could arise. At the moment of these conceptual designs completion, the tank placement is not certain. This means the quantity of materials and construction methods need to be flexible to accommodate uncertainty.

The RWH system will also require automated controls. The systems will need to automatically switch to municipal backup supplies if the cistern is dry, perform back-flushing of filters when pressure loss increases, and manage disinfection dosing. Controls can also perform ongoing monitoring and communication. It is common to measure cistern levels, water usage, pump hours, UV bulb life, and other important system information. Communication over the Internet can provide remote monitoring and alert capabilities as well.

Cross-contamination of the potable water system is a critical concern for any water reuse system. Cross-contamination measures for rainwater reuse systems will be similar to those for reclaimed and gray water systems. When rainwater is integrated as a significant supply source for a non-potable indoor use, a potable make-up supply line is needed for dry periods and when the collected rainwater supply is unable to meet water demands. The make-up supply to the cistern is the point of greatest risk for cross-contamination of the potable supply. Codes will require a backflow prevention assembly on the potable water supply line, an air gap, or both. In addition to backflow prevention, the use of a designated, dual piping system is also necessary. Purple pipes, indicating reused water, are most often used to convey rainwater and are accompanied by pipe stencilling and point-of-contact signage that indicates the water is non-potable and not for consumption.

Day-tanks provide a convenient location to provide an air gap between potable and reuse water. Pressure tanks can also be used with back-flow preventers, allowing pumps to cycle less frequently. Most systems will incorporate municipal make-up water to ensure the end-use application — such as toilet flushing or irrigation — is not interrupted during dry periods.
3. RAIN WATER HARVESTING SYSTEM DESIGN AND REQUIREMENTS

The design of the RWH system takes into account a wide range of criteria. The geographical location and its annual rainfall; the area and type of catchment or collection surface; the intended applications, now and in the future, and compliance with applicable international codes, standards and regulations.

Implementation of these systems requires proper design to: 1) determine optimal cistern sizing based on collection and water demand characteristics, 2) incorporate water quality treatment, 3) engineer piping and related drainage configurations, 4) identify suitable cistern locations, and 5) configure an appropriate distribution system for the harvested water. The contents of this section approach the first two points.

3.1 RAIN WATER STORAGE AND TANK SIZING - WATER PRODUCTION AND NEEDS

For sizing purposes of the rainwater harvesting system the monthly water balance method is applied. This method assumes a volume of rainwater that can be collected and stored, adding the volume of water captured each month by relating average monthly rainfall and catchment area, and subtracting the demand.

Rainfall

The rainwater amount which can be harvested is calculated using the mean annual rainfall data. Mean annual is the statistical average calculated on the basis of measured rainfall over many years. It has to be understood that there is no guarantee that the calculated amount will be achieved, but there is 95% likelihood that this amount can be expected. This near certainty diminishes to a probability if the rainfall pattern in a given area differs substantially. This is quite common in countries with drought periods like Tunisia.

Rainfall is the most unpredictable variable in the calculation and hence, to determine the potential rainwater yield for a given catchment, reliable rainfall data are required, preferably for a period of at least 10 years. Available rainfall data for the catchment if study is summarised below, average mean rainfall is given for each month. Average annual rainfall is calculated by taking the sum of historical rainfall available and dividing by the number of years of recorded data.

The runoff volumes that can be potentially harvested are calculated using:

\[
\text{Water Harvesting Potential (m}^3\text{)} = \frac{R \times A \times C \times ACE}{1000}
\]
Where:

\[ R \text{ – Rainfall (mm)} = \text{Monthly average rainfall from Table 1} \]

A - Catchment Area (m2) = 27,000 (basin 3 and 4)

C - Runoff Coefficient = 0.9

ACE - Assumed Collection Efficiency (0.9) = 90

Table 4. Monthly average rainfall data for the city of Sousse in Tunisia.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Jan</td>
<td>164,7</td>
<td>6,5</td>
<td>30,3</td>
<td>61,7</td>
<td>62,86</td>
</tr>
<tr>
<td>Feb</td>
<td>2</td>
<td>21,3</td>
<td>44</td>
<td>20,6</td>
<td>20,99</td>
</tr>
<tr>
<td>Mar</td>
<td>15</td>
<td>54,6</td>
<td>11,5</td>
<td>24,8</td>
<td>25,30</td>
</tr>
<tr>
<td>Apr</td>
<td>49,1</td>
<td>10,7</td>
<td>27,6</td>
<td>26,8</td>
<td>27,26</td>
</tr>
<tr>
<td>May</td>
<td>8</td>
<td>25,5</td>
<td>71,6</td>
<td>32,2</td>
<td>32,79</td>
</tr>
<tr>
<td>June</td>
<td>1,7</td>
<td>2,4</td>
<td>23,7</td>
<td>8,5</td>
<td>8,67</td>
</tr>
<tr>
<td>July</td>
<td>2,4</td>
<td>0</td>
<td>7</td>
<td>2,9</td>
<td>2,93</td>
</tr>
<tr>
<td>Aug</td>
<td>9,5</td>
<td>0</td>
<td>0</td>
<td>2,9</td>
<td>2,96</td>
</tr>
<tr>
<td>Sept</td>
<td>119,5</td>
<td>40,3</td>
<td>6,8</td>
<td>51,0</td>
<td>51,97</td>
</tr>
<tr>
<td>Oct</td>
<td>25,9</td>
<td>49,8</td>
<td>63,4</td>
<td>42,6</td>
<td>43,39</td>
</tr>
<tr>
<td>Nov</td>
<td>0</td>
<td>23,8</td>
<td>91,6</td>
<td>35,3</td>
<td>36,00</td>
</tr>
<tr>
<td>Dec</td>
<td>7,2</td>
<td>7,2</td>
<td>24</td>
<td>11,8</td>
<td>11,98</td>
</tr>
<tr>
<td>TOTAL</td>
<td>405</td>
<td>242,1</td>
<td>401,5</td>
<td>321,0</td>
<td>327,11</td>
</tr>
</tbody>
</table>


Irrigation Demand - Reference Evapotranspiration

Reference evapotranspiration (ETo) for Sousse is calculated with ETo calculator software according to Land and Water Division FAO standards. ETo represents the evapotranspiration rate from a reference surface, not short of water. A large uniform grass field is considered worldwide as the reference surface. The reference crop completely covers the soil, is kept short, well watered and is actively growing under optimal agronomic conditions.

The ETo calculator assesses ETo from meteorological data by means of the FAO Penman-Monteith equation. This method has been selected by FAO as the reference because it closely approximates grass ETo at the location evaluated, is physically based, and explicitly incorporates both physiological and aerodynamic parameters.
Available climatic data have been taken for Sousse on different websites (Temperatures, dew point, wind speed, etc.). For Missing data for some weather variables at Sousse, procedures are used by the ETo calculator for estimating specific climatic conditions according to methodologies outlined in the Irrigation and Drainage Paper No 56.: “Crop Evapotranspiration”. By selecting appropriate lower and upper limits for meteorological data, the program applies a quality check when specifying or importing data. The FAO Penman-Monteith equation is given by:
In Eq. 2, the value 0.408 converts the net radiation $R_n$ expressed in MJ/m$^2$/day to equivalent evaporation expressed in mm/day. Because soil heat flux is small compared to $R_n$, particularly when the surface is covered by vegetation and calculation time steps are 24 hours or longer, the estimation of $G$ is ignored in the ET$_o$ calculator and assumed to be zero. This corresponds with the assumptions reported in the FAO Irrigation and Drainage Paper n° 56 for daily and 10-daily time periods. Allen et al. (1989) state that the soil heat flux beneath the grass reference surface is relatively small for that time period.

Table 5. Climate data for Sousse used for the calculation of reference evapotranspiration and results obtained according to the FAO Penman-Monteith equation.

<table>
<thead>
<tr>
<th>Month</th>
<th>Temperature (ºC)</th>
<th></th>
<th>Ave. Wind Speed (m/sec)</th>
<th>Mean daily sunshine hours (hour/day)</th>
<th>ET$_o$ (mm/day)</th>
<th>ET$_o$ (mm/month)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ave. high</td>
<td>Ave. Low</td>
<td>Daily Mean</td>
<td>Ave. Dew Point (ºC)</td>
<td>Ave. Wind Speed</td>
<td>Mean daily sunshine hours</td>
<td>ET$_o$</td>
</tr>
<tr>
<td>Jan</td>
<td>15,8</td>
<td>11,4</td>
<td>7</td>
<td>8</td>
<td>5,5</td>
<td>6</td>
</tr>
<tr>
<td>Feb</td>
<td>16,3</td>
<td>11,7</td>
<td>7,2</td>
<td>8</td>
<td>2,5</td>
<td>7</td>
</tr>
<tr>
<td>March</td>
<td>17,8</td>
<td>13,3</td>
<td>8,9</td>
<td>9</td>
<td>5,5</td>
<td>7</td>
</tr>
<tr>
<td>April</td>
<td>20,2</td>
<td>15,6</td>
<td>11</td>
<td>10</td>
<td>6,1</td>
<td>8</td>
</tr>
<tr>
<td>May</td>
<td>23,4</td>
<td>18,7</td>
<td>14,1</td>
<td>14</td>
<td>5,5</td>
<td>10</td>
</tr>
<tr>
<td>June</td>
<td>27,1</td>
<td>22,4</td>
<td>17,8</td>
<td>17</td>
<td>5,5</td>
<td>11</td>
</tr>
<tr>
<td>July</td>
<td>30,7</td>
<td>25,6</td>
<td>20,6</td>
<td>19</td>
<td>5</td>
<td>12</td>
</tr>
<tr>
<td>August</td>
<td>31,5</td>
<td>26,2</td>
<td>20,9</td>
<td>21</td>
<td>4,7</td>
<td>11</td>
</tr>
<tr>
<td>Sept.</td>
<td>30,2</td>
<td>25</td>
<td>19,9</td>
<td>20</td>
<td>5,5</td>
<td>9</td>
</tr>
<tr>
<td>Oct.</td>
<td>25,6</td>
<td>20,9</td>
<td>16,3</td>
<td>17</td>
<td>5,5</td>
<td>7</td>
</tr>
<tr>
<td>Nov.</td>
<td>20,8</td>
<td>16,1</td>
<td>11,5</td>
<td>12</td>
<td>3,05</td>
<td>7</td>
</tr>
<tr>
<td>Dec.</td>
<td>16,7</td>
<td>12,4</td>
<td>8,1</td>
<td>8</td>
<td>3,05</td>
<td>6</td>
</tr>
</tbody>
</table>
Water Balance

To calculate water demand and irrigation needs 16,000 m² of football field are considered. The monthly water balance is estimated by subtracting ET from the average rainfall. When water balance drops below the ET, the irrigation is needed.

The storage capacity of the cistern is variable and dependent. In general, the larger the tank, the greater the volume of rainwater that can be collected and stored during rainfall events (collection efficiency). Factors, such as local rainfall patterns, catchment area and rainwater demand, limit the amount of rainfall that can be collected and utilized by the system. Given the catchment area and once the rainwater demands and local rainfall patterns are determined the storage capacity of the tank has been calculated to provide the best balance between collection efficiency of the RWH system and minimizing its size and cost.

Different variables of catchment area, volume of storage and water demand were studied and compared. For the input data the monthly amount of water that can be captured, accounting for dry spells, is less than monthly estimated demand. Additional catchment area could be considered in a future detailed design if stormwater management and reuse is a strong driver for installing a RWH.

The water balance results of the tank and the different input parameters and results are presented on the tables below.

Table 6. Monthly Irrigation demands for the total area of soccer grass fields (16,000 m²) in the Complexe de L’Étoile Du Sahel.

<table>
<thead>
<tr>
<th>Month</th>
<th>Ave. Monthly Rainfall (mm/month)</th>
<th>Reference Evapotranspiration ET₀</th>
<th>Irrigation Demand for Total Area</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>m³/month</td>
</tr>
<tr>
<td>January</td>
<td>62.86</td>
<td>55.80</td>
<td>0</td>
</tr>
<tr>
<td>February</td>
<td>21.00</td>
<td>53.20</td>
<td>606</td>
</tr>
<tr>
<td>March</td>
<td>25.00</td>
<td>89.90</td>
<td>1,222</td>
</tr>
<tr>
<td>April</td>
<td>27.26</td>
<td>123.00</td>
<td>1,802</td>
</tr>
<tr>
<td>May</td>
<td>32.79</td>
<td>145.70</td>
<td>2,125</td>
</tr>
<tr>
<td>June</td>
<td>8.67</td>
<td>174.00</td>
<td>3,112</td>
</tr>
<tr>
<td>July</td>
<td>2.93</td>
<td>210.80</td>
<td>3,913</td>
</tr>
<tr>
<td>August</td>
<td>2.96</td>
<td>186.00</td>
<td>3,445</td>
</tr>
<tr>
<td>September</td>
<td>51.97</td>
<td>153.00</td>
<td>1,902</td>
</tr>
<tr>
<td>October</td>
<td>43.39</td>
<td>105.40</td>
<td>1,167</td>
</tr>
<tr>
<td>November</td>
<td>36.00</td>
<td>63.00</td>
<td>508</td>
</tr>
<tr>
<td>December</td>
<td>11.98</td>
<td>49.60</td>
<td>708</td>
</tr>
<tr>
<td>Totals</td>
<td>326.81</td>
<td>1409.40</td>
<td>20,511</td>
</tr>
</tbody>
</table>
Table 7. Input parameters used to calculate water balances.

<table>
<thead>
<tr>
<th>INPUT PARAMETERS</th>
<th>QUANTITY</th>
<th>UNIT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Area Draining to Cistern</td>
<td>27,000</td>
<td>m²</td>
</tr>
<tr>
<td>Landscape Area to be Irrigated</td>
<td>16,000</td>
<td>m²</td>
</tr>
<tr>
<td>Irrigation Efficiency</td>
<td>0.85</td>
<td></td>
</tr>
<tr>
<td>Ave. Runoff Coefficient</td>
<td>0.9</td>
<td></td>
</tr>
<tr>
<td>ETo</td>
<td>Table 5</td>
<td>mm</td>
</tr>
<tr>
<td>Average Rainfall</td>
<td>Table 6</td>
<td>mm</td>
</tr>
<tr>
<td>Potable water costs</td>
<td>1.19*</td>
<td>TND / m³</td>
</tr>
</tbody>
</table>

* JORT N°105 du 31 décembre 2013.

Table 8. Optimized cistern volume for the input parameters.

<table>
<thead>
<tr>
<th>RESULTS</th>
<th>QUANTITY</th>
<th>UNIT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cistern Volume</td>
<td>400</td>
<td>m³</td>
</tr>
<tr>
<td>Annual Runoff Captured &amp; Reused</td>
<td>78.3</td>
<td>%</td>
</tr>
<tr>
<td>Non-Potable Demand Met by Rainwater Harvesting for Irrigation</td>
<td>27</td>
<td>%</td>
</tr>
<tr>
<td>Potential annual savings</td>
<td>6658</td>
<td>TND</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>MONTH</th>
<th>RUNOFF TO CISTERN (M³)</th>
<th>IRRIGATION NEEDS (M³)</th>
<th>ENDING CISTERN VOLUME (M³)</th>
<th>WATER CAPTURED (M³)</th>
<th>WATER REUSED (M³)</th>
<th>OVERFLOW * (M³)</th>
<th>NET AVAILABLE VOLUME (M³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>September</td>
<td>1.137</td>
<td>1.902</td>
<td>0</td>
<td>1.023</td>
<td>1.023</td>
<td>0</td>
<td>-879</td>
</tr>
<tr>
<td>October</td>
<td>949</td>
<td>1.167</td>
<td>0</td>
<td>854</td>
<td>854</td>
<td>0</td>
<td>-313</td>
</tr>
<tr>
<td>November</td>
<td>787</td>
<td>508</td>
<td>200</td>
<td>709</td>
<td>508</td>
<td>79</td>
<td>200</td>
</tr>
<tr>
<td>December</td>
<td>262</td>
<td>708</td>
<td>0</td>
<td>236</td>
<td>436</td>
<td>0</td>
<td>-272</td>
</tr>
<tr>
<td>January</td>
<td>1.375</td>
<td>0</td>
<td>400</td>
<td>400</td>
<td>0</td>
<td>975</td>
<td>1.237</td>
</tr>
<tr>
<td>February</td>
<td>459</td>
<td>606</td>
<td>207</td>
<td>413</td>
<td>606</td>
<td>0</td>
<td>207</td>
</tr>
<tr>
<td>March</td>
<td>547</td>
<td>1.222</td>
<td>0</td>
<td>492</td>
<td>699</td>
<td>0</td>
<td>-522</td>
</tr>
<tr>
<td>April</td>
<td>596</td>
<td>1.802</td>
<td>0</td>
<td>537</td>
<td>537</td>
<td>0</td>
<td>-1.266</td>
</tr>
<tr>
<td>May</td>
<td>717</td>
<td>2.125</td>
<td>0</td>
<td>645</td>
<td>645</td>
<td>0</td>
<td>-1.480</td>
</tr>
<tr>
<td>June</td>
<td>190</td>
<td>3.112</td>
<td>0</td>
<td>171</td>
<td>171</td>
<td>0</td>
<td>-2.941</td>
</tr>
<tr>
<td>July</td>
<td>64</td>
<td>3.913</td>
<td>0</td>
<td>58</td>
<td>58</td>
<td>0</td>
<td>-3.855</td>
</tr>
<tr>
<td>August</td>
<td>65</td>
<td>3.445</td>
<td>0</td>
<td>58</td>
<td>58</td>
<td>0</td>
<td>-3.387</td>
</tr>
<tr>
<td><strong>Totals</strong></td>
<td><strong>7.147</strong></td>
<td><strong>20.511</strong></td>
<td></td>
<td><strong>5.595</strong></td>
<td><strong>5.595</strong></td>
<td><strong>1.053</strong></td>
<td></td>
</tr>
</tbody>
</table>

*The cistern overflow can be used for other non-potable water demands like street cleaning increasing the total volume of water.
3.2 WATER QUALITY FLOW RATE

Different parameters are needed for the calculation of design flows for the Advance Runoff Treatment System (ARTS), runoff coefficient, time of concentration, rainfall intensity and return periods to consider.

The Rational formula estimates the peak rate of runoff at any location in a watershed as a function of the drainage area, runoff coefficient and mean rainfall intensity for a duration equal to the time of concentration. The results of using the Rational formula to estimate water quality flow rate are very sensitive to the intensity parameters used. The Rational formula is expressed as follows:

\[
WQF = \frac{It \cdot S \cdot C}{3.6}
\]

Where:

- \(Q\) : maximum rate of runoff (m3/s)
- \(C\) : runoff coefficient representing a ratio of runoff to rainfall (dimensionless)
- \(It\) : Rainfall intensity to treat the 90th cumulative percentile volume of the annual runoff, mm/h
- \(A\) = drainage area tributary to the design location, km2

Intensity

The design criteria for the Advance Runoff Treatment System manufactured is flow based and performance is dependent on a prescribed particle size gradation. Flow based sizing, however does not mean treatment of design storms (i.e., 2 to 100 year storms which are typically applied for quantity control design) but rather treating the flows that contribute to the majority of the average annual runoff volume, called the water quality flow rate (WQF). The WQF is selected based on treating the 80th to 90th cumulative percentile volume of the annual runoff.

The plot of the intensity distribution curve, Figure 10, illustrates that for incremental changes at the lower range of flow rates a large incremental change in volume occurs. This is illustrated by a steep rising slope at the lower intensities and consequently associated flow rates. This large incremental change in volume is due to the fact that the majority of the rainfall events consist of small storms and contributes to a greater percentage of the annual volume of runoff due to frequency of occurrence. Conversely, for the larger flow rates, the slope of the curve levels out and the increase in volume captured is marginal. This illustrates that large storm events occur less frequently and the volume of runoff contributed do not make up the majority of the annual runoff volume. The inflection point or “knee” of the graph is typically found at the 80th to the 90th percentile of the annual runoff volume. The rate of return on the volume of runoff treated rapidly diminishes after the “knee”. The cost to build a treatment facility to treat a higher flow rate or runoff volume is much greater than the return on removal efficiency since large storms occur infrequently. In addition, the gain in water quality
benefits would be less as the additional gain in volume treated is minimal when compared to the total annual volume of runoff.

**Fig. 10.** Intensity Distribution Curve by Cumulative Annual Volume of Runoff, Mediterranean City of Tortosa (Alicante, Spain).

Historical rainfall data for a 10 year period are not available or have not been provided for the city of Sousse. The intensity distribution curves by cumulative annual volume of runoff cannot be calculated so the rainfall intensity is selected from the Intensity-Duration-Frequency (IDF) curves for rainfall events in the geographical region of interest under the following assumptions:

- The 1 year RP intensities are greater than the intensity associated to the WQF.
- \( I_t = 18 \text{ mm/h} \) will produced at least the 90% of annual cumulative rainfall volume.
- Design flows for the ARTS will be exceeded at least once a year.

**Table 9.** Rainfall intensities for different return periods and durations for the station of Sousse, Tunisia (Ecole Polytechnique Fédérale de Lausanne).
The rainfall intensity selected for the return period of 1 year is 18 mm/h. This intensity will generate a WQF that will allow intercepting and treating a portion of the runoff from all storms and all the runoff from 90% of the storms that occur on average during the course of a year from the contributing catchment.

Runoff Coefficient

The Rational method runoff coefficient (c) is a function of the soil type and drainage basin slope. A simplified table is shown below.

<table>
<thead>
<tr>
<th>LAND USE</th>
<th>C</th>
<th>LAND USE</th>
<th>C</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Business:</strong></td>
<td></td>
<td><strong>Lawns:</strong></td>
<td></td>
</tr>
<tr>
<td>Downtown areas</td>
<td>0.70 - 0.95</td>
<td>Sandy soil, flat, 2%</td>
<td>0.05 - 0.10</td>
</tr>
<tr>
<td>Neighbourhood</td>
<td>0.50 - 0.70</td>
<td>Sandy soil, avg., 2-7%</td>
<td>0.10 - 0.15</td>
</tr>
<tr>
<td>areas</td>
<td></td>
<td>Sandy soil, steep, 7%</td>
<td>0.15 - 0.20</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Heavy soil, flat, 2%</td>
<td>0.13 - 0.17</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Heavy soil, avg., 2-7%</td>
<td>0.18 - 0.22</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Heavy soil, steep, 7%</td>
<td>0.25 - 0.35</td>
</tr>
<tr>
<td><strong>Residential:</strong></td>
<td>0.30 - 0.50</td>
<td><strong>Agricultural land:</strong></td>
<td></td>
</tr>
<tr>
<td>Single-family areas</td>
<td>0.40 - 0.60</td>
<td>Bare packed soil</td>
<td></td>
</tr>
<tr>
<td>Multi units, detached</td>
<td>0.60 - 0.75</td>
<td>*Smooth</td>
<td></td>
</tr>
<tr>
<td>Multi units, attached</td>
<td></td>
<td>*Rough</td>
<td></td>
</tr>
<tr>
<td>Suburban</td>
<td>0.25 - 0.40</td>
<td>Cultivated rows</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>*Heavy soil, no crop</td>
<td>0.30 - 0.60</td>
</tr>
<tr>
<td></td>
<td></td>
<td>*Heavy soil, with crop</td>
<td>0.20 - 0.50</td>
</tr>
<tr>
<td></td>
<td></td>
<td>*Sandy soil, no crop</td>
<td>0.20 - 0.40</td>
</tr>
<tr>
<td></td>
<td></td>
<td>*Sandy soil, with crop</td>
<td>0.10 - 0.25</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Pasture</td>
<td>0.15 - 0.45</td>
</tr>
<tr>
<td></td>
<td></td>
<td>*Heavy soil</td>
<td>0.05 - 0.25</td>
</tr>
<tr>
<td></td>
<td></td>
<td>*Sandy soil Woodlands</td>
<td>0.05 - 0.25</td>
</tr>
<tr>
<td><strong>Industrial:</strong></td>
<td>0.50 - 0.80</td>
<td><strong>Streets:</strong></td>
<td></td>
</tr>
<tr>
<td>Light areas</td>
<td>0.60 - 0.90</td>
<td>Asphaltic</td>
<td>0.70 - 0.95</td>
</tr>
<tr>
<td>Heavy areas</td>
<td></td>
<td>Concrete</td>
<td>0.80 - 0.95</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Brick</td>
<td>0.70 - 0.85</td>
</tr>
<tr>
<td>Parks, cemeteries</td>
<td>0.10 - 0.25</td>
<td>Unimproved areas</td>
<td>0.10 - 0.30</td>
</tr>
<tr>
<td>Playgrounds</td>
<td>0.20 - 0.35</td>
<td>Drives and walks</td>
<td>0.75 - 0.85</td>
</tr>
<tr>
<td>Railroad yard areas</td>
<td>0.20 - 0.40</td>
<td>Roofs</td>
<td>0.75 - 0.95</td>
</tr>
</tbody>
</table>

Table 10. Rainfall coefficients for different land uses and slopes.
For the project a value of 0.9 is used for the area of study for all the catchment contributing to the generation of runoff into the RWH system. This value includes a safety factor for the calculation as most of the catchment is not impervious.

Time of concentration

Time of concentration is a fundamental watershed parameter. It is used to compute the peak discharge for a watershed. The time of concentration is calculated applying the formula:

\[ T_c = 0.3 \left( \frac{L}{J^{0.4}} \right)^{0.76} \]

Where:

- \( T_c \): Time of concentration in hours.
- \( L \): Maximum length of water travel in Km.
- \( J \): Average slope of the catchment in parts per unit

The peak discharge is a function of the rainfall intensity, which is based on the time of concentration. Time of concentration for the catchment of study is under 10 minutes so \( T_c = 10 \) min. The hourly rainfall intensity determined previously to calculate WQF is bigger than the intensity related to the \( T_c = 10 \) min. As a safety factor the rainfall intensity for 60 min duration and PR = 1 year is used for the WQF.

WQF

The Rational equation is the simplest method to determine peak discharge from drainage basin runoff. It is not as sophisticated as the SCS TR-55 method, but is the most common method used for sizing sewer systems. The WQF rate and the parameters used for the calculation are presented on the table below.

<table>
<thead>
<tr>
<th>CATHCMENT ID</th>
<th>CATCHMENT</th>
<th>TC (min)</th>
<th>C</th>
<th>WQF (m³/sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area (Ha)</td>
<td>Length (Km)</td>
<td>Slope (m/m)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>1,6</td>
<td>0.4855</td>
<td>10</td>
<td>0.9</td>
</tr>
<tr>
<td>4</td>
<td>1,10</td>
<td>0.0095</td>
<td>10</td>
<td>0.9</td>
</tr>
</tbody>
</table>

3.3 WATER QUALITY – POLLUTANT LOADINGS

The Simple Method estimates stormwater runoff pollutant loads for urban areas. The technique requires a modest amount of information, including the sub watershed drainage area and impervious cover, stormwater runoff pollutant concentrations, and
annual precipitation. Land use for the catchment of study is defined as residential and associated stormwater annual pollutant loads for the type of land are taken from the tables of the Simple Method, the even mean concentrations used for the calculations are:

- Total Suspended Solids: 100 mg/l
- Total Nitrogen: 2,2 mg/l
- Total Phosphorous: 0,4 mg/l

Fecal coliform is more difficult to characterize than other pollutants. Data are extremely variable, even during repeated sampling at a single location. Because of this variability, it is difficult to establish different concentrations for each land use. For this calculation the simple method median urban runoff default value, derived from NURP data of 20,000 CFU/100ml is assumed.

Stormwater pollutant concentrations can be estimated from local or regional data or from national data sources when available.

The Simple Method estimates pollutant loads for chemical constituents as a product of annual runoff volume and pollutant concentration, as:

\[ L = R \times C \times PC \times A \times 10 \]

Where:

- \( L \): Annual Load (kg/year).
- \( R \): Annual Rainfall (cm)
- \( C \): Runoff Coefficient
- \( PC \): Pollutant Concentration (mg/l)
- \( A \): Catchment Area (km²)

For bacteria, the equation is slightly different, to account for the differences in units. The modified equation for bacteria is:

\[ L = 10,0204 \times 10^{5} \times R \times CB \times A \]

Where:

- \( L \): Annual Load (thousand millions colonies).
- \( R \): Annual Rainfall (cm)
- \( CB \): Bacteria Concentration (CFU/100 ml)
- \( A \): Catchment Area (km²)
Table 12. Annual stormwater pollutant loadings estimation for the contributing catchments of study.

<table>
<thead>
<tr>
<th>CATCHMENT ID</th>
<th>Area (Km²)</th>
<th>Annual Runoff (cm)</th>
<th>C</th>
<th>Annual Pollutant Loadings</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>TN (kg/year)</td>
</tr>
<tr>
<td>3</td>
<td>0.016</td>
<td>32.7</td>
<td>0.9</td>
<td>10.4</td>
</tr>
<tr>
<td>4</td>
<td>0.011</td>
<td>32.7</td>
<td>0.9</td>
<td>7.1</td>
</tr>
</tbody>
</table>

The Simple Method provides reasonable estimates of changes in pollutant export resulting from urban development activities. However, several caveats should be kept in mind when applying this method. The simple method provides a general planning estimate of likely storm pollutant export from areas at the scale of a development site, catchment or subwatershed. More sophisticated modelling may be needed to analyze larger and more complex watersheds.

Advanced Runoff Treatment System (ARTS)

The ARTS sizing and selection considers the pollutant annual loadings and event mean concentrations and forms. The ARTS implemented shall be able to remove 80% of the pollutant loadings present in the stormwater at the WQFR to comply with the water safety codes and standard for rainwater use.

A) Settling

The Downstream Defender ® can be sized for different treatment goals and objectives. For design purposes, the selected model's Treatment Flow Rate should be greater than or equal to the site's Water Quality Flow Rate. In this case the hydraulic capacity of the selected model should be considered with respect to the peak discharge flow rate from the site.

Table. 13. Hydrodynamic Vortex Separator Performance Specifications from vendor for sizing purposes.

<table>
<thead>
<tr>
<th>Diameter</th>
<th>Max Depth¹</th>
<th>MTFR-50²</th>
<th>MTFR-100²</th>
<th>Scour Flow Rate³</th>
<th>PTFR⁴</th>
<th>Headloss⁵</th>
<th>Oil Storage Capacity⁶</th>
<th>Sediment Storage Capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>(feet)</td>
<td>(mm)</td>
<td>(l/s)</td>
<td>(l/s)</td>
<td>(l/s)</td>
<td>(l/s)</td>
<td>(mm)</td>
<td>(litres)</td>
<td>(litres)</td>
</tr>
<tr>
<td>4</td>
<td>1245</td>
<td>34</td>
<td>45</td>
<td>68</td>
<td>85</td>
<td>207</td>
<td>265</td>
<td>533</td>
</tr>
<tr>
<td>6</td>
<td>1788</td>
<td>96</td>
<td>122</td>
<td>184</td>
<td>227</td>
<td>290</td>
<td>817</td>
<td>1605</td>
</tr>
<tr>
<td>8</td>
<td>2337</td>
<td>195</td>
<td>249</td>
<td>376</td>
<td>425</td>
<td>335</td>
<td>2044</td>
<td>3554</td>
</tr>
<tr>
<td>10</td>
<td>2877</td>
<td>340</td>
<td>425</td>
<td>668</td>
<td>708</td>
<td>366</td>
<td>3975</td>
<td>6650</td>
</tr>
</tbody>
</table>
Notes:

1. Depth measurement is from the outlet invert to top of the bottom slab.
2. MTFR-50 and MTFR-100 are the Maximum Treatment Flow Rates for removing target particle sizes of 50 microns and 100 microns, respectively.
3. Scour Flow Rates are based on testing that demonstrates retention of captured sediment having a D50 of 100. Effluent concentrations shall not exceed 20 mg/L.
4. PTFR or Peak Treatment Flow Rate is based on the HVS maintaining positive removal efficiencies and headlosses no greater than those listed above for each model.
5. Headlosses are the difference in water elevations upstream and downstream of the HVS as determined by ASTM C1745 / C1745M – 11. The headlosses listed above for any particular model are for that HVS operating at the Peak Treatment Flow Rate.

Based on full-scale laboratory trials and independent studies, a 8-ft diameter Downstream Defender will achieve at least an 90% TSS removal efficiency for 50 micron mean particle size at an operating flow rate of 195 l/s. Based on the WQF for the project the 8 ft diameter unit is selected as the first level treatment of the ARTS. Thu Hydrodinamic vortex separator shall meet the following criteria to provide an adequate level of treatment:

- Performance of the HVS shall be based on independent full-scale laboratory and/or field testing and shall adhere to the Performance Specifications listed in Table 1. The laboratory testing used as the basis of product performance shall be undertaken in accordance with testing protocols approved or endorsed by SWEMA or acceptable State agency, such as a State Department of Environmental Protection (DEP) or recognized verification agency (e.g.: ETV, NJCAT, NETE).
- Performance of the HVS shall be based on treating the Water Quality Flow rate (WQF) without internally bypassing and without re-suspension and washout of captured pollutants (scour). The Maximum Treatment Flow Rate(s) (MTFR-50 and/or MTFR-100) shall be greater than or equal to the WQF. The HVS shall remove greater than or equal to 80% of TSS based on the Target Particle Size (TPS) of 50 microns and/or 100 microns at MTFR-50 and MTFR-100, respectively.
- The HVS shall treat all flows without internally bypassing up to the Peak Treatment Flow Rate (PTFR). Full-scale independent laboratory scour testing shall demonstrate effluent control of less than or equal to 20 mg/L for all flows up to 150% of MTFR-100 without internal or external bypass.
- The HVS shall be capable of capturing and retaining fine silt and sand size particles. Analysis of captured sediment from full-scale field installations shall demonstrate particle sizes predominately in the 20-micron range.
- The HVS shall capture and retain 100% of all floating trash and debris and remove greater than 80% of hydrocarbons up to its rated storage capacities under conditions of a catastrophic spill such as might be experienced in an automobile or truck accident spill like conditions.

B) Filtration
The stormwater quality filter treatment device shall remove oil, debris, trash, coarse and fine particulates (TSS), particulate-bound pollutants, metals and nutrients from stormwater during runoff events. The Up-Flo™ Filter is a compact treatment-train device that targets the wide range of contaminants typically found in water runoff.

Each Up-Flo™ Filter includes a sedimentation sump, coarse screens and polishing filter media. Coarse grit and gross debris is removed by settling in the sump, neutrally buoyant debris is removed by screening, and fine suspended sediment is removed by filtration. The filter media shall have the possibility to be customized to target other site-specific pollutants such as metals and organics.

The stormwater quality filter treatment device shall treat 100% of the required water quality treatment design flow considering the maximum treatment flux rate across each individual filtration media. For the WQF a 60 module UpFlo filtration Vault is considered that shall have proof by verified bodies a field test result providing:

- **Suspended Solids Removal** - The stormwater quality filter treatment device shall have demonstrated a minimum median TSS removal efficiency of 85% and a minimum median SSC removal efficiency of 95%.

- **Fine Particle Removal** - The stormwater quality filter treatment device shall have demonstrated the ability to capture fine particles as indicated by a minimum median removal efficiency of 75% for the particle fraction less than 25 microns, an effluent d50 of 15 microns or lower for all monitored storm events.

- **Turbidity Reduction** - The stormwater quality filter treatment device shall have demonstrated the ability to reduce the turbidity from influent from a range of 5 to 171 NTU to an effluent turbidity of 15 NTU or lower.

- **Nutrient (Total Phosphorus & Total Nitrogen) Removal** - The stormwater quality filter treatment device shall have demonstrated a minimum median Total Phosphorus removal of 55%, and a minimum median Total Nitrogen removal of 50%.

- **Metals (Total Zinc & Total Copper) Removal** - The stormwater quality filter treatment device shall have demonstrated a minimum median Total Zinc removal of 55%, and a minimum median Total Copper removal of 85%.

The filtration device for the RWH will separate a minimum of 85% mass of the Sil-Co-Sil 106 (d50 = 22 microns), with a confidence interval of 95% to 100% at the WQF for influent concentrations ranging from 100 to 300 mg/ of TSS.
Fig. 11. Sil-Co-Sil 250 and 106 particle size gradations to be used for the sizing of the filtration system forming the ARTS.

The treatment criteria for managing operational risks of the RWH system will depend on the nature of the scheme. Advice on design criteria could be sought from the manufacturers of pumps and irrigations system components likely to be sensitive to stormwater pollution. A further consideration is the expected design life of sensitive elements (e.g., irrigation nozzles or drippers). Table 14 provides an indication of potentially suitable treatment criteria for public, open-space irrigation, in the absence of product-specific information (most elements are likely to have a design life of less than 20 years).

Table 14. Indicative stormwater treatment criteria for public, open-space irrigation—managing operational risks

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Stormwater treatment criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Design life up to 20 years</td>
</tr>
<tr>
<td>Suspended solids</td>
<td>&lt;50 mg/L</td>
</tr>
<tr>
<td>Coarse particles</td>
<td>&lt;2 mm diameter</td>
</tr>
<tr>
<td>Iron (total)(^a)</td>
<td>&lt;10 mg/L</td>
</tr>
<tr>
<td>Phosphorus (total)(^a)</td>
<td>&lt;0.8 mg/L</td>
</tr>
<tr>
<td>Hardness (CaCO(_3))(^a)</td>
<td>&lt;350 mg/L</td>
</tr>
</tbody>
</table>

\(^a\) Derived from ANZECC–ARMCANZ (2000a).
3.4 WATER QUALITY SANITARY RISK

Commercial RWH system collecting surface water need to have special considerations with the quality of rainwater and the need for treatment must be evaluated in situ through monitoring before and after the installation of the system. Treatment needs should be determined on a case by case basis by local building or health authorities, considering the recommendations of designers and preferences of end users.

For the RWH system advanced pre-storage treatment devices are incorporated as part of the conveyance network that rely on gravity flow to facilitate the treatment process and save energy. Additionally, post-storage treatment devices requiring pressurized flow and/or electricity are included to aid in the treatment process.

Ground level or trafficked surfaces provide large areas for collection and may be used in areas where there is a high demand for non-potable water. The proposed catchment surfaces carry a greater risk of pollutants entering the system and before implementing the system a specific risk assessment needs to be completed following clause 8 of the BS 8515:2009 Rainwater harvesting systems – Code of practice or similar recognized standard.

The treatment systems considered should provide a sufficient level of treatment for non-potable uses when correctly installed and maintained. Nonetheless the risk assessment should be used to identify the need for any further quality control measures, including monitoring of the harvested water and compliance with water reuse norms.

The potential microbiological contaminants and vectors that can be present in harvested runoff and that are probably of greatest concern are *E. Coli*, *Cryptosporidium*, *Giardia lamblia*, total coliforms, legionella, fecal coliforms, and viruses. Rainwater should be tested to ensure that none of them are found. County health department and city building code staff should also be consulted concerning safe, sanitary operations and construction of rainwater harvesting systems.
4. REQUIREMENTS, NORMS AND GUIDELINES

Further guidance on systems for greywater and rainwater re-use can be found in the following French norms:

- Code civil français, article 641.
- Code civil français, articles 640 alinéa 3 et 641 alinéa 2.
- Code civil français: article 681.
- Guide technique de la gestion des eaux pluviales dans les projets d'aménagement, DDAF 37
- Réglementation sanitaire et départementale, article 16-3.
- Arrêté du 21 août 2008 relatif à la récupération des eaux de pluie et à leur usage à l'intérieur et à l'extérieur des bâtiments.
- Guide de bonne pratique « Règles et bonnes pratiques à l'attention des installateurs ». (document DHUP QC2).
- NF P16-005 Octobre 2011 - Systèmes de récupération de l'eau de pluie pour son utilisation à l'intérieur et à l'extérieur des bâtiments

Applicable Codes, Standards, and Guidelines of reference at an International level that should also be considered for the RWH System installation:

- BS 8515:2009 'Rainwater Harvesting Systems, Code of Practice',
- DIN 1989-1 Rainwater harvesting systems - Part 1: Planning, installation, operation and maintenance
- CIRIA Project Report 80 "Rainwater and greywater use in buildings: Decision making for water conservation."
5. BUDGET ESTIMATION

1) DESIGN AND ENGINEERING

Preparation of Plans, Specifications and Estimations

Subtotal 28.454 €

2) PROCUREMENT OF THE RWH

Total 2 - 211.820 €

2.1. Advance Runoff Treatment System

Advanced Hydrodynamic Vortex Separator (AHVS) for stormwater treatment, with flow-modifying internal components that minimize turbulence and prevent any flow from internally bypassing the separation region within the vortex chamber. Performance of the AHVS shall be based on treating the Water Quality Flow rate (WQF) of 121 l/s without internally bypassing and without re-suspension and washout of captured pollutants (scour). The Maximum Treatment Flow Rate shall be greater than or equal to the WQF. The AHVS shall remove greater than or equal to 80% of TSS based on the Target Particle Size (TPS) of 50 microns and/or 100 microns at 195 l/s and 249 l/s, respectively. Concrete manhole for the AHVS included.

Subtotal 25.950 €

Multi-stage stormwater treatment system with processes that combine pretreatment with fluidized bed upward filtration technology for superior filtration rates and drain down systems for media longevity. Performance of the system shall be based on treating the Water Quality Flow rate (WQF) without internally bypassing and without re-suspension and washout of captured pollutants (scour). The Maximum Treatment Flow Rate shall be greater than or equal to the WQF of 121 l/s. The system shall remove greater than or equal to 90% of TSS based on the Target Particle Size (TPS) of 20 microns and a minimum removal of 50% of all the particles up to 3 microns. Concrete vault for the filtration system included.

Subtotal 103.562 €

2.2. Cistern

Large diameter gravity or low pressure profile wall pipe cistern made from high density polyethylene (HDPE) resin with a capacity of 425 m3. Includes compartments for
treated water, for tertiary treatment installation, all suitable connections, registration chambers and auxiliary components.

Subtotal 55.500 €

2.3. Disinfection System

Stormwater disinfection system with low-pressure, high output (LoHi) amalgam UV lamps in a piped system inside a hydraulically optimized reactor chamber for up to 20 m³/h with flange connectors control modes and SCADA communications. The system shall be able to treat water with low UV transmittance and achieve maximum disinfection performance even with turbid water. The systems shall have a selective calibrated UV intensity sensor for energy savings.

Subtotal – 14.258 €

2.4. Pumps, Plumb and Control Units

Rain Water harvesting pump to deliver a flow of reclaimed water of up to 40 m³/h with float and connected to the control monitors that will balance water available in RWH System against the water level needed to assure proper pump performance. Includes municipal make-up water inlet to ensure end-use applications are not interrupted during dry periods, Control of the submersible pump with “dry run” protection, Isolation of the rainwater harvesting system form the mains supply, Control panel and monitoring remote system. All in accordance with water regulations applicable.

Subtotal - 12.550 €

3) CONSTRUCTION

Total 3- 72.722 €

Civil works including clearing and removal of all obstacles within the limits of the earthworks; the excavation of all cuts, including excavation below the final subgrade surface; the excavation of borrow areas, granular fill layers, benches and surface drainage facilities; the carting of the excavated material to fill or waste; and construction of the fills and subgrade and grade; shaping, trimming, grassing and maintaining of other areas. In general all the civil works required to install all the RWH system by the contractor.

Subtotal - 72.722 €

TOTAL COST RWH SYSTEM ................................................................. 312.996 €
6. EXPECTED BENEFITS

Water Conservation - Water resources in dry areas in Tunisia are under strong pressure, which seriously threatens their sustainability. This situation may get worse over the years, especially with the climate change and the intensification of agricultural practices. Rainwater could play a role in future management of water resources and in the solutions required to address water stress. It is explicitly encouraged within the International Codes and is widely accepted to be necessary to achieve awarding of ‘credits’ for water savings from rainwater at LEED and BREEAM certifications and standards.

Water resources in Tunisia are characterized by scarcity and a pronounced irregularity. RWH can be easily adopted as an integrated strategy for the use of water complementing the complex and diverse water infrastructure that the country has to mobilize and exploit available water resources. RWH presents an alternative to make better use of the existing irrigation infrastructures (PPIs and wells) and to enhance water resources and compensate for excessive withdrawals from the shallow wells in the region of Tunisia.

Projects aimed at developing water reuse have been proposed such as the implementation of the water reuse strategies for the Great Tunis and other major cities, ground water recharge of some coastal aquifers, industrial reuse of reclaimed water, etc. (SERAH, 2002). The proposed project has a potential to show an example of RWH integration to water resources management and could gain wider acceptance in the future.

Public Outreach and Sustainability Benefit – Increasing public awareness and advocacy of environmental programs such have created a public relations benefit for public and private entities that are viewed as environmentally responsible. The LEED program “promotes sustainable building and design practices through a suite of rating systems” which identify and award credit for sustainable design choices. Included in the LEED rating system is a category for Water Efficiency, which includes credit for both stormwater management and water conservation. Rainwater harvesting systems are well-suited to achieving these Water Efficiency goals and can be used to achieve multiple LEED certification points. The construction of green buildings and municipal developments has a number of tangible benefits to building owners including positive perception among consumers and potential customers and the ability to attract tenants and charge increased rental rates or taxes.

Energy Use and Environmental Benefit – A significant amount of energy is required to extract, treat, and distribute water. A reduction in energy use also translates to reduced carbon emissions. Although difficult to quantify for individual system owners, the value
of these benefits can be significant in a larger scale cost-benefit analysis of rainwater harvesting at a commercial level.

**Environmental and Ecological Impacts** – Rainwater harvesting systems are an effective means for on-site stormwater management and are considered a Low Impact Development technique which helps to match the hydrology of developed land to the pre-development condition. Widespread use of this practice, however, particularly with indoor use of harvested water, may significantly alter the water balance of a site as compared to pre-development hydrology.
7. POTENTIAL BARRIERS

Individual client requirements and site restrictions must be considered by the designer to provide a project specific ‘detailed approach’. Until sufficient information is available for a complete assessment of the proposed application the technical feasibility of the RWH system cannot be determined. All the information provided in this document is preliminary, all plans, specifications, assumptions and requirements of a RWH system will need further study and review. Furthermore client’s requirements, site restrictions have not been considered and will need to be addressed in the future by the designer to provide a project specific ‘detailed approach’.

Rainwater that is captured and stored correctly is a safe, economical and sustainable source of quality water. Rainwater is as safe as any source of water, provided certain safety precautions are taken as part of water capture, storage and distribution. Understanding the sources of stormwater pollution is particularly important to the practice of rainwater harvesting to prevent health risks or unnecessary distribution of pollutants at the site of study.

A perceived lack of economic benefit is often cited as a barrier to more widespread implementation of rainwater harvesting systems. High upfront costs and easy access to low-cost municipal or private water sources in Tunisia could lead some to discount the water conservation benefits of stormwater capture and on-site use. However, recent trends in water demand and water prices, coupled with the growing number of regulatory and economic incentives for stormwater management, indicate a need for a more detailed cost-benefit analysis of harvesting systems. The long-term cost-effectiveness and return on investment for rainwater harvesting systems depend on a number of factors. A full cost-benefit analysis is out of the scope of this report.
8. RECOMMENDATIONS / NEXT STEPS

Effectiveness of the rainwater harvesting depends on appropriate design of the systems, which is in turn dependant on good quality input information. As with any design, the first step needed is to determine with precision all the technical information required and that has not been available for the present study (Irrigation needs, precise hydrologic data, detailed plans of the drainage system, water quality data, client requirements, etc.)

Local council or other regulatory authority should be contacted to determine whether there are any specific requirements for stormwater reuse schemes, including requirements for planning and operational approval before any additional step or further action is taken. The scheme should be developed and operated to meet any such requirements. The codes and standards used for this conceptual design do not override any state, territory or council requirements.

Stormwater monitoring at the proposed site should be taken for the characterization of the relevant contaminants present in the runoff. Increasing the knowledge of runoff to the harvested will aid in the better understanding of the associated health and environmental risks before proceeding with the project.

The authority responsible for issuing planning approvals for a stormwater reuse scheme (commonly a local council) should seek information from applicants relating to health and environmental risk management, including:

- How public health and safety risks will be addressed during the design and operation of the system
- How and by whom will the system will be managed on an ongoing basis
- What (if any) risks or financial obligations will be transferred to council if it operates the scheme (eg. operations, maintenance, monitoring and reporting costs).