Application of the E\textsuperscript{2}STORMED Decision Support Tool in Ħaż-Żabbar
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1. Pilot City Description

- General description: Population, urban area, location map...
  - Locality Total Population: 15,224 (Source: Government Gazette 1st June 2012 as at 31st March 2012)
  - Yearly growth of population: Malta & Gozo: 0.45%
    Zabbar: 0.17% (As per November 2011 Census for the years 2005-2011)
  - Total area (km²) Zabbar: 5.76 km²
  - Total catchment area: 500,000 sq.m.
  - Open spaces include: Playing fields
    Parking Areas
    Squares
  - Public Buildings include: Schools
    Civic Centre (incl. Local council premises)

*As at 31st March 2012 (Source: Government Gazette 1st June 2012)*
Map of Malta
Map of Zabbar
Climate

Rainfall and temperature data for the Maltese Islands

<table>
<thead>
<tr>
<th>Month</th>
<th>Rainfall (mm)</th>
<th>Max. temp. (°C)</th>
<th>Min. temp. (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>January</td>
<td>86.4</td>
<td>14.9</td>
<td>10.0</td>
</tr>
<tr>
<td>February</td>
<td>57.7</td>
<td>15.2</td>
<td>10.0</td>
</tr>
<tr>
<td>March</td>
<td>41.8</td>
<td>16.6</td>
<td>10.7</td>
</tr>
<tr>
<td>April</td>
<td>23.2</td>
<td>18.5</td>
<td>12.5</td>
</tr>
<tr>
<td>May</td>
<td>10.4</td>
<td>22.7</td>
<td>15.6</td>
</tr>
<tr>
<td>June</td>
<td>2.0</td>
<td>27.0</td>
<td>19.2</td>
</tr>
<tr>
<td>July</td>
<td>1.8</td>
<td>29.9</td>
<td>21.9</td>
</tr>
<tr>
<td>August</td>
<td>4.8</td>
<td>30.1</td>
<td>22.5</td>
</tr>
<tr>
<td>September</td>
<td>29.5</td>
<td>27.7</td>
<td>20.9</td>
</tr>
<tr>
<td>October</td>
<td>87.8</td>
<td>23.9</td>
<td>17.7</td>
</tr>
<tr>
<td>November</td>
<td>91.4</td>
<td>20.0</td>
<td>14.4</td>
</tr>
<tr>
<td>December</td>
<td>104.3</td>
<td>16.7</td>
<td>11.4</td>
</tr>
</tbody>
</table>


- Annual average rainfall: 1947 – 2004: 569mm

Water resources

The two main sources of urban water supply in the Maltese Islands are groundwater and desalinated seawater.

Public groundwater sources include boreholes and pumping stations. The latter consist of horizontal radiating galleries dug in the rock slightly above sea level in order to skim freshwater from the top of the freshwater lenses that constitute the sea-level aquifers.

Currently, the WSC operates three seawater RO plants at Lapsi, Cirkewwa and Pembroke through its subsidiary company Malta Desalination Services Ltd.


WSC stated that, in general, water from the desalination plants and from the ground water abstraction are stored in reservoirs in a 60:40 ratio. There are around 26 of these reservoirs in the Maltese Islands. Water is then supplied from these reservoirs to the water supply network on the islands.
In Malta one can find both a perched aquifer and a mean sea level aquifer. Their locations are indicated on the above plan and their characteristics are described below.

Perched aquifer

Some aquifers located within Upper Coralline Limestone are considered perched aquifers if these lie on top of the impervious Blue Clay formation and above sea level. Such aquifers are not in contact with seawater and hence do not suffer from saltwater intrusion. A perched aquifer is characterised by its low permeability (0.2 –0.5 meters per year) and high porosity (41-45 per cent). This means that the rate of downwards movement in the aquifer matrix will be slow and the travel time in the unsaturated zone will be long in the thicker parts of the aquifer. The depth of the perched aquifer varies between 20 and 50 meters.
The conceptual model for the perched aquifers

Main sea level aquifer

The Lower Coralline Limestone formation hosts the mean sea level aquifer. This aquifer consists of freshwater that floats in a lens-shaped formation above saline sea water due to differences in water density. The current highest piezometric level in this aquifer is around three meters. Due to abstraction pressures, the piezometric levels in some central regions can reach levels as low as one meter above mean sea level. The mean sea level aquifer is characterised by relatively low porosity levels (7 – 20 per cent) and a downward movement rate of 0.5 – 2.8 meters per year. Yet, the thickness of the Malta aquifers suggests that residence times in the saturated zone range between 15 and 40 years. The longest residence times occur within the Gozo mean sea level aquifer and range between 25 and 60 years

The conceptual model for the MSL aquifer

Sources:


Aquifer Plan – MEPA
Groundwater quality

Only 23 million cubic meters of groundwater are sustainably available for extraction, but it is conservatively estimated that 34 million cubic meters are being extracted. This over-extraction is of serious concern as it lowers the quality of the remaining groundwater.

Groundwater is a lens-like body of freshwater floating on seawater, stored deep underground in porous rocks. It is only replenished by rainwater which gets absorbed into the ground and slowly, over a period of decades, percolates into groundwater bodies. Since only a fixed amount of rainwater is making its way into groundwater bodies every year, that is the amount that is sustainably available for extraction.

Extracting more however, decreases the volume of freshwater within the aquifer, displacing it with increasing amounts of seawater. The result is that the remaining groundwater increases in salinity. This has already happened to several of Malta aquifers. Furthermore, over-extraction is not the only threat facing Malta’s groundwater. Trends in fertilizing agricultural land over the past few decades have led to excessive nitrates coming into contact with rainwater. Rainwater dissolves these nitrates and carries them down into the aquifers. Since nitrates are a cancerous substance, the amount of nitrates which can be considered safe in drinking water is fixed at 50 ppm.

Between excessive nitrates and excessive salinity due to over-extraction, the water produced by 90% of Malta’s aquifers no longer meets the Maltese and EU standards for safe drinking water.

To restore Malta’s groundwater to a good status it is important to balance extraction with recharge. A key element in this is reducing wasteful consumption by increasing the efficiency with which we consume water.

Source: www.investinginwater.org

W2 NITRATE AND CHLORIDE LEVELS AT ABSTRACTION BOREHOLES

Key policy question: Does groundwater quality meet EU standards?

In 2004 nitrate (NO₃) levels in Malta’s groundwaters exceeded the Nitrate Directive trigger value of 50 mg/l at two thirds of the WSC abstraction boreholes. Exceedences were most notable in the perched aquifer system, where the highest value was 132 mg/l at ‘Marina’. The highest nitrate level found in the sea level aquifer system was 85 mg/l at the Speranza borehole. The fresh water lens that makes up Malta’s mean sea level aquifer system is particularly vulnerable to localised seawater intrusion. Chloride concentrations, indicating salinity, in this groundwater body all exceeded the WHO drinking water standard of 250 mg/l, which may be used as a benchmark for groundwater but remains a very high standard in this context. Concentrations range from 1,736 mg/l at Ta’ Kandja to 354 mg/l at Xewkija, Gozo. The perched aquifer system is also slightly at risk from salinity, with values ranging from 209 mg/l at Bingemma to 163 mg/l at Fakka near Rabat.

Source: MRA (2005)
Main water supply from boreholes

Public groundwater production sources in the Maltese Islands

Source: WSC
The main characteristics of a typical supply borehole can be summed as follows:

Boreholes are generally vertical shafts averaging 300 mm in diameter with the first few metres being cased. The normal depth ranges from 50 metres to well over 150 metres depending mainly on the topography of the borehole site. The normal geology of the site dictates the output capacity with secondary permeabilities due to fissures mainly being the main characteristics for a good output. Typically, the Mean Sea Level Aquifer is the major groundwater body (aquifer) with the first 30 metres being normally inside the Globigerina Limestone (Franka stone) with the rest being in the underlying Lower Coralline Limestone (Qawwi ta’ Isfel). In order to abstract groundwater from this borehole, a submersible pump/motor unit is lowered inside the borehole with a string of pipes (either 2 inch or 3 inch in diameter, galvanised pipes) attached to the pump. This pipe is then hooked up to the pumping main to the reservoir at the surface.

It should be noted that apart from the boreholes, groundwater is also abstracted through pumping stations where a series of galleries running at sea level conveys groundwater from a distance to a central shaft from where it is pumped to the distribution reservoirs.

All groundwater is disinfected by the use of Chlorine gas.

Source: WSC

Water supply treatment processes

Potable water is derived from both groundwater and seawater sources. The groundwater is sourced from a galleries and boreholes system operated by WSC. There are a total of 42km of underground galleries that include the 6.2km galleries at Ta’ Kandja. A system of pumping stations and transfer mains connect water sources to storage reservoirs.

The water from the three desalination plants at Lapsi, Cirkewwa and Pembroke and that from the ground water abstraction is mixed together in a 60:40 ratio. This blend is stored in the 24 reservoirs in Malta, Gozo and Comino which have a total capacity of 400,000 cubic meters.

All the production, transfer and storage of water is controlled and monitored in real time by remote sensing from the Control Room based at Luqa. Reservoir levels, flow rates and pressures are kept at optimal operating parameters at all times.

In general there is only one form of treatment namely chlorine disinfection. Another form of water treatment carried out on groundwater is RO polishing at Ta’ Cenc, Gozo.

Source: WSC
Water supply from desalination

Seawater is extracted from deep shore wells sunk in Coralline Limestone. This configuration has produced very good quality water, free from silt and organic material. The feed water boost pumps serve the dual purpose of providing the pressure required to filter seawater through 5 micron cartridge filters and also provide adequate suction pressure for the high-pressure pumps’ inlet. The former ensure silt free water to the membranes at all times, and the latter provide the pressure required to drive the desalination process. At a pressure of 83 bar (69 bar at Ghar Lapsi Reverse Osmosis), acidified seawater (or brackish water) is fed into semi-permeable membranes that separate the feed stream into potable water and brine. The residual brine stream, still at high pressure, is piped into an energy recovery device, which retrieves the energy available in this stream. The low pressure brine is returned to sea. The potable water produced is disinfected by chlorine addition and remineralised by the addition of lime. The final stage in the process is the pumping of the product into the distribution network.
Cirkewwa - Reverse Osmosis Plant

Started Operating: 1988

Nominal Capacity: 18,600m$^3$/day

Number of Trains: 2 × 3,000m$^3$/day - 3 × 4,200m$^3$/day

Configuration: Single Pass

Recovery: 42 per cent

Operating Pressure: 83 Bar (1200 PSI)

Feed Intake: Beach Wells

Feed TDS: 39,000 mg/l

Feed Temperature: 19°C
Pembroke - Reverse Osmosis Plant

Started Operating: 1993

Nominal Capacity : 54,000 m³/day

Number of Trains : 6 × 4,400 m³/day - 6 × 4,600 m³/day

Configuration : Single Pass

Recovery : 45 per cent

Operating Pressure : 83 Bar (1200 PSI)

Feed Intake : Beach Wells

Feed TDS : 39,000 mg/l

Feed Temperature : 19°C
Ghar Lapsi - Reverse Osmosis Plant

Started Operating: 1982

Nominal Capacity: 24,000m³/day

Number of Trains: 12 × 2,000m³/day

Configuration: Single Pass

Recovery: 33 per cent

Operating Pressure: 69 Bar (1000 PSI)

Feed Intake: Beach Wells

Feed TDS: 39,000 mg/l

Feed Temperature: 19 - 25 °C

Source: www.wsc.com.mt
Desalination treatment processes in each plant

PLANT OPERATION

Submersible Pumps force seawater directly from the shore-wells into the plant feed reservoir. The seawater is then pumped at low pressure through the required amount of cartridge filters and directly into the suction inlet of the HP pumps.

The seawater is then pumped through the membranes at pressures of approximately 60 – 70 bar and by reverse osmosis 42% of the feed water is converted into potable water. The remaining 58% reject is returned through the Energy Recovery devices to convert high pressure reject hydraulic energy into useful power which is used to assist the electric motor in providing the high pressure seawater. In this way, the power required from the electricity grid by the RO process is reduced by about 35%.

During the process, sulphuric acid is injected in the seawater to lower the pH of the water into the membranes, whilst calcium hydroxide and chlorine are injected in the permeate stream to re-mineralize the water and make it fit for human consumption.

The permeate water is pumped away into the distribution system and WSC reservoirs.
PLANT EQUIPMENT

The plant utilizes several types of equipment, each suited to the area of application.

Wellfield

Extracting seawater is achieved by lowering submersible pumps in drilled boreholes to a depth of about 30m. The pumped water is then led to a feedwater reservoir in the plant.

Pre-treatment

The pre-treatment process uses vertical turbine pumps to lift the water from the reservoir and into cartridge filters which remove particles larger than 5 microns.

Conversion Process

The equipment used at the stage varies between the different areas of the plant and has been the subject of ongoing improvement throughout the years as it is the major area of energy consumption.

Conversion of seawater into potable water is done through high pressure pumps utilizing the latest technology to recover energy from the brine stream. Energy used for conversion (excluding pre-treatment pumping) is 2.8kwhr/m3.

Post-treatment

The post-treatment process is the final stage before the water reaches end consumers, and also uses vertical turbine pumps to pump the water from the permeate reservoir into the WSC distribution network after being re-mineralized and sterilized.

Source: WSC
Water management system

Water courses in the urban area

There is one watercourse passing through Haz-Zabbar, namely Wied il-Ghajn as indicated in the map presented in the next section. In the Zabbar area, this watercourse is an asphalted road, which then leads to Marsascala. In the area of Marsascala, the watercourse passes partly through an asphalted road and partly through a natural valley. The area in Marsascala experiences events of pluvial flooding. Eventually this watercourse leads to the sea in Marsascala bay.

Map where the catchment areas of these water courses are in relation to the urban area (if applicable)

Malta Watercourses
Gozo & Comino watercourses

Watercourses as indicated in the South Malta Local Plan
Water Supply distribution

The distribution network in Malta is composed of just over 2,300km of mains pipes mostly consisting of ductile iron, cement-mortar lined pipes (66%) or cast iron unlined pipes (18%). Other mains pipes are made of galvanized iron or polyethylene. There are also around 140,000 water service connections feeding 255,000 customers, which is 100% penetration. All customers are metered. The total maximum potable water storage capacity for the Maltese islands is around 400,000m³. This figure is divided into 350,000m³ for Malta and 50,000m³ for Gozo. There are 24 potable water reservoirs in all (17 in Malta, 6 in Gozo and 1 on Comino). The network is divided into around 300 zones and sub-zones (District Metered Areas) all of which are metered and logged. There are also a number of distribution booster stations (8 in Malta and 9 in Gozo). These are equipped with 19 variable speed drives on pumps, for better pressure control. Automation is also achieved in the network itself, with over 200 Pressure Reducing Valves installed, with 28 having automated control.

Source: WSC

Important losses in the water distribution system

The Water Services Corporation has been actively managing leakage since the mid-nineties. When the leakage amount was first quantified, in 1995, this stood at a staggering 3,900m³/hr with the corresponding Infrastructure Leakage Index (ILI) over 10. Now, the leakage amount is down to below 500m³/hr with the ILI around 2.3 for the Maltese Islands (2012). These large gains have been achieved by promoting a five-force methodology, which is approved and recommended by the International Water Association. This strategy includes the rationalisation of the water distribution network, water pressure management, active leakage localisation, efficient leak repairs and the replacement of critically-weak segments of the distribution network.

Source: WSC

Tariff system for households, industry and services water supply.

WSC Water tariffs

<table>
<thead>
<tr>
<th>Bands m³</th>
<th>Present tariff per m³ (€)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Domestic (NoP=0)</td>
<td></td>
</tr>
<tr>
<td>≤33</td>
<td>2.30</td>
</tr>
<tr>
<td>&gt;33</td>
<td>5.41</td>
</tr>
<tr>
<td>Domestic (NoP≠0)</td>
<td></td>
</tr>
<tr>
<td>≤33</td>
<td>1.47</td>
</tr>
<tr>
<td>&gt;33</td>
<td>5.41</td>
</tr>
<tr>
<td>Non Residential</td>
<td></td>
</tr>
<tr>
<td>≤168</td>
<td>2.10</td>
</tr>
<tr>
<td>169 and ≤ 40,000</td>
<td>2.50</td>
</tr>
<tr>
<td>&gt; 40,000</td>
<td>1.75</td>
</tr>
</tbody>
</table>

In Malta water is metered by each household.
No, water used for park irrigation and streets cleaning is not metered.

In Zabbar, water is sourced from a water reservoir at St James Square, which is sometimes used by the Environmental Landscaping Consortium. There are also two reservoirs at Gnien il-Kunsill in Triq il-Kunvent and another one in Gnien il-Mistieh in Triq l-Ghakrux (outside the area under study), which are used by the Zabbar Local Council for watering.

Furthermore, a large closed reservoir has recently been constructed by the central government adjacent to a distributor road in the area.

The cost per unit of water used for irrigation is not available.

Sources: www.wsc.com.mt and Zabbar Local Council
● Water related issues and challenges

*Only a small amount of storm water is being collected for reuse.*

*Rainfall in Malta is different from the other countries in Europe; we usually have flash flooding.*

*The size of household cisterns.*

*Household roof drains illegally connected to the sewage system.*

*Storm Water is not always good for use as it may be contaminated.*

*The use of potable water for irrigation of public landscaping.*

*The entity to be responsible for the maintenance of the SuDS is to be identified.*

*Sea water infiltration into the drainage system in low-lying areas.*
2. **Pilot Case 1: Developed Area**

2.1. **General Description**

- Location map of this area.

- Main characteristics: number of households, population, drainage area, drainage system...

In general storm water in Ħaż-Żabbar is surface runoff, storm water flows on the surface of residential roads, down to the adjacent village, Marsascala, where it will then flow directly into the open sea. In some particular areas the storm water is collected via gratings and conveyed through underground pipe / culverts. Storm water is then discharged into reservoirs or else into valleys/green areas.
<table>
<thead>
<tr>
<th></th>
<th>Number of Residents</th>
<th>Number of Households</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ħaż-Żabbar</td>
<td>12219</td>
<td>5649</td>
</tr>
<tr>
<td>Existing Development within Selected Area</td>
<td>3623</td>
<td>1722</td>
</tr>
</tbody>
</table>

*according to electoral register

- Main problems/issues to be solved. Potential for improvement of stormwater management.
  - Rainfall in Malta is different from the other countries in Europe; we usually have flash flooding.
  - The size of household cisterns.
  - Household roof drains illegally connected to the sewage system.
  - Stormwater is not always good for re-use as it may be contaminated.
  - The use of potable water for irrigation.
  - The entity to be responsible for the maintenance of the SuDS needs to be identified.

- Expected energy benefits with SuDS option.

Green Roof (Extensive) provides insulation and can lower heating and cooling costs for the building. Reduced the amount of potable water which would be needed for irrigation.

Household rain harvesting system reduces the amount of potable water by reusing storm water for flushing toilets, washing machines and irrigation hence reducing energy for its production and transportation.
2.2. **GENERAL MODEL DATA**

- Description of data included in this menu. How have they been obtained?

![](General_data.png)

- **A.** The Country where the urban area analysed is located is Malta.

- **B.** Economic units: The national monetary units for Malta are Euro.

- **C.** Electricity price: Cost of electricity in the analysed urban area is €0.162 exclusive of VAT. This is the Non-Residential rate per kWh obtained from Enemalta website.

- **D.** Electricity emissions: The default values (values of 2010) of the CO₂ emissions produced per KWh of electricity consumption was used as there is no data available for Malta.

- **E.** Period of analysis: 40 years return period was considered for Malta.

- **F.** Economic discount rate: The economic discount rate used for Malta is 3%.

- **G.** Rainfall distribution: The monthly average rainfall in the urban area was obtained from FAO (2006) Malta, Water Resources Review
• **H. Temperatures distribution:** The hourly temperature for 365 consecutive days was obtained for the Malta from Meteorological Office. The average daily temperatures variation in summer and in winter in the urban area were then extracted from this data.

• **I. Flood events:** For these scenarios the return periods of considered flood events is considered to be 10 years.
If applicable, comparison between real data available and default values proposed in this menu.

This is not applicable.
2.3. Scenario 1: Conventional Development

2.3.1. General description

- General description of proposed solution.

- The proposed storm water solution for this part of Ħaż-Żabbar is a conventional system where storm water flowing on the surface of residential roads is collected via gratings and conveyed through underground pipes and directed to Structural Detention Facility. Storm water will flow through this structure with a settling unit to remove sediment and other pollutants.

When one comes to start planning a new projects, cost is one of detrimental factors. The approach we used for comparing the performance of these two scenarios is ‘limited by budget’ approach. We have chosen infrastructures that would have the same cost in the period of analysis. The question we asked is; ‘How much can we undertake for a fixed budget?’ This results of this approach would show the advantages/disadvantages of using SuDS over the conventional system when the cost for both system is the same.

- Map of these solutions.

2.3.2. Drainage infrastructures included in the scenario

- Description of included infrastructures.

  - Conventional Pipe Network System – It collects the urban storm water and conveys it as rapidly as possible to the outflow point avoiding flooding in streets and houses. This will be a separated system, there will be a separate system for waste water.
Structural Detention Facility will effectively remove sediment oil, and floating and sinking debris from the collected storm water, prior to discharge.

- Design criteria followed in each infrastructure.

The catchment areas around the site in question were identified and divided into 3 sections: Agricultural areas, Built-Up areas and Asphalted areas (Discharge Coefficients, $\psi = 0.3, 0.7, 0.9$ respectively). The cumulative impermeable area is then calculated. The flow, $Q$, to be catered for is therefore identified. uPVC was identified as the material to be used for the pipes. According to the diameter and gradient of the proposed pipes, the pipe capacity is generated using Mannings formula and this should be greater than the flow $Q$. Flow $Q$ of the rainfall was generated from the rain intensity. From statistical data, it had been established that the intensity of a 15-minute storm which occurs once every year (1 in 1 year) which is used locally for such calculations for normal stormwater networks in roads. This amounts to a value of 179 l/s/ha.

Summary of values included in the DST.

<table>
<thead>
<tr>
<th>Construction and maintenance</th>
<th>Scenario 1: Pipe network</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Total Area of Drainage</strong></td>
<td>52,334 m$^2$</td>
</tr>
<tr>
<td><strong>Total length of Pipe Network</strong></td>
<td>1,430 m</td>
</tr>
<tr>
<td>Unitary construction cost (€/unit)</td>
<td>200.00</td>
</tr>
<tr>
<td>Unitary energy consumption during construction (kWh/unit)</td>
<td>32.32</td>
</tr>
<tr>
<td>Unitary CO$_2$ emissions during construction (kgCO$_2$/unit)</td>
<td>9.56</td>
</tr>
<tr>
<td>Unitary maintenance cost (€/year/unit)</td>
<td>0.77</td>
</tr>
<tr>
<td>Unitary energy consumption during maintenance (kWh/year/unit)</td>
<td>*</td>
</tr>
<tr>
<td>Unitary CO$_2$ emissions during maintenance (kgCO$_2$/year/unit)</td>
<td>*</td>
</tr>
<tr>
<td>Lifespan (years)</td>
<td>35</td>
</tr>
<tr>
<td>Unitary construction cost (€/m)</td>
<td>NA</td>
</tr>
</tbody>
</table>

*No Local Values obtained yet.
### Construction and maintenance
**Scenario 1: Structural Detention Facility**

**Total Area of Drainage:** 52,334m² (Infrastructure connected directly to pipe network).
**Total Volume of Infrastructure:** 400m³

<table>
<thead>
<tr>
<th></th>
<th>400.00</th>
<th>210.00</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unitary construction cost (€/unit)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unitary energy consumption during construction (kWh/unit)</td>
<td>849.29</td>
<td>*</td>
</tr>
<tr>
<td>Unitary CO₂ emissions during construction (kgCO₂/unit)</td>
<td>269.02</td>
<td>*</td>
</tr>
<tr>
<td>Unitary maintenance cost (€/year/unit)</td>
<td>1.5</td>
<td>1.75</td>
</tr>
<tr>
<td>Unitary energy consumption during maintenance (kWh/year/unit)</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>Unitary CO₂ emissions during maintenance (kgCO₂/year/unit)</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>Lifespan (years)</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>Unitary construction cost (€/m)</td>
<td>NA</td>
<td>NA</td>
</tr>
</tbody>
</table>

*No Local Values obtained yet.*

---

Process followed to estimate construction and maintenance costs.

*The unitary cost for each infrastructure was estimated from first principles as per bill of quantities below;*
<table>
<thead>
<tr>
<th>Earthworks</th>
<th>Quantity</th>
<th>Unit</th>
<th>Rate</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Excavate trench in any type of material to a depth not exceeding 2.5 metres and cart away material to an approved dumping site. Rate is to include for shuttering, shoring, falsework, pumping, protection from ingress of any type of water, dewatering and provision of dry conditions for the laying of buried plant. Rate shall include any required dumping charges. No extra payments shall be made for working around or along other existing buried infrastructure.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>400mm</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>1,716.00</td>
<td>m³</td>
<td>33.00</td>
<td>€ 56,628.00</td>
</tr>
<tr>
<td>2 400mm internal diameter thermoplastic solid wall Upvc drain pipe; in trenches; as per drawing RCD/500/71. Depths to invert not exceeding 2 metres.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>1,430.00</td>
<td>m</td>
<td>113.30</td>
<td>€ 162,019.00</td>
</tr>
<tr>
<td>Chambers and Gullies</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stormwater Chambers</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3 Type B Chamber as per drawing RCD/500/06, D400 Grating. Depth to invert exceeding 1 metre but not exceeding 2 metres.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>25.00</td>
<td>no.</td>
<td>1,045.00</td>
<td>€ 26,125.00</td>
</tr>
<tr>
<td>Stormwater Gullies</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4 Concrete gullies 600mm x 600mm as per drawing RCD 500/69, D400 Grating. Depth to invert not exceeding 1 metre.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>28.00</td>
<td>no.</td>
<td>682.00</td>
<td>€ 19,096.00</td>
</tr>
<tr>
<td>Trench Backfilling</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5 Provide, spread, level and vibrate lean concrete as per Series 2600, Clause 2603 and finish off.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>1072.50</td>
<td>m³</td>
<td>66.00</td>
<td>€ 70,785.00</td>
</tr>
<tr>
<td>6 Unbound material Type 1, Average 200mm thick. In carriageway, hard shoulder and hard strip.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>228.80</td>
<td>m³</td>
<td>19.80</td>
<td>€ 4,530.24</td>
</tr>
<tr>
<td>Pavement</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7 Asphalt concrete 0/25mm Base Course, 80mm thick, In carriageway.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>1,144.00</td>
<td>m²</td>
<td>26.03</td>
<td>€ 29,778.32</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td></td>
<td>€ 368,961.56</td>
</tr>
<tr>
<td>Total Length of pipe in meters</td>
<td></td>
<td></td>
<td></td>
<td>1430</td>
</tr>
<tr>
<td>Average rate per m</td>
<td></td>
<td></td>
<td></td>
<td>€ 258.02</td>
</tr>
</tbody>
</table>
A summary of the unitary estimated costs for construction and maintenance is shown below;

<table>
<thead>
<tr>
<th>Ref.</th>
<th>TYPE</th>
<th>UNIT</th>
<th>Construction /EURO</th>
<th>Maintenance /EURO per year</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>PIPE NETWORK</td>
<td>per m run</td>
<td>€ 258.02</td>
<td>€ 2.00</td>
</tr>
<tr>
<td>2</td>
<td>STRUCTURAL DETENTION FACILITY</td>
<td>per m3</td>
<td>€ 231.41</td>
<td>€ 1.75</td>
</tr>
</tbody>
</table>

- Process followed to estimate energy consumed and emissions during construction and maintenance.

  Several attempts were made to estimate the energy consumed and emissions during construction and maintenance. However there is no data available for Malta to carry out such calculations.
2.3.3. Water reuse

This part should be complete if the corresponding tab has been completed in the DST.

*The water reused in Scenario 1 is 0 m$^3$ as none of the infrastructures proposed has the capacity to store storm water for reuse.*

- Description of data included in this tab. How have they been obtained?
  
  *Not Applicable*

- If applicable, comparison between real data available and results obtained with the estimation panel.
  
  *Not Applicable*

- Global results obtained in this tab.
  
  *Not Applicable*

2.3.4. Stormwater runoff

- Description of the hydraulic model used to analyze runoff.

  *The catchment areas around the site in question were identified and divided into 3 sections: Agricultural areas, Built-Up areas and Asphalted areas. The Discharge Coefficients for each area were applied for Agricultural areas $\psi = 0.3$, Built-Up areas $\psi = 0.7$ and for Asphalted areas $\psi = 0.9$. The cumulative impermeable area was then calculated.*

- Comparison between hydraulic model results and runoff results obtained with the estimation panel.

  *The results obtained cannot be compared with the default values as the discharge coefficients have already been applied to the value for the drainage area inputted.*

- Global results obtained in this tab.

  *The total runoff volume obtained in the storm water runoff tab is 28318 m$^3$*

2.3.5. Conveyance and treatment

*This tab was not completed as in Malta storm water is neither pumped nor treated before it is released into the environment.*

- Description of data included in this tab. How have they been obtained?

  *Not Applicable*
• If applicable, comparison between real data available and results obtained with the estimation panel.

  *Not Applicable*

• Global results obtained in this tab

  *Not Applicable*

2.3.6. Water quality

• Qualitative water quality results included in this tab.

  *No water quality tests were carried out, the runoff catchment characteristics were assumed to be from a commercial zone as it is the land use which produces the worst runoff quality. The sensitivity of the receiving water was assumed to be low as storm water is discharged in open waters. Give the above the estimated global outflow water was consider to be of low quality.*

• Other analysis/data about water quality in this scenario.

  *No other data was collected on the water quality for this scenario.*

2.3.7. Flood protection

This part should be complete if the corresponding tab has been completed in the DST.

  *In Malta there is no hydraulic data available for the selected area. The number of flooded households and the average damage per household were estimated for each case.*

• Description of the hydraulic model used to obtain flooding areas.

  *Not Applicable*

• Description of the method used to estimate economic consequences of flooding in each case.

  *Not Applicable*

• If applicable, comparison between real data available and results obtained with the estimation panel.

  *Not Applicable*

2.3.8. Building insulation

*This part should be complete if the corresponding tab has been completed in the DST.*
• Description of data included in this tab. How have they been obtained?

• If applicable, comparison between real data available and default values used in the estimation panel.

• Global results obtained in this tab.

2.3.9. Summary

• Please, copy the summary tables obtained in this tab.

Results Table

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Conventional Development</th>
<th>Development with SuDS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Financial cost</td>
<td>Energy consumption</td>
</tr>
<tr>
<td>Construction of infrastructures</td>
<td>452940.00</td>
<td>385933.60</td>
</tr>
<tr>
<td>Maintenance of infrastructures</td>
<td>3560.00</td>
<td>12.04</td>
</tr>
<tr>
<td>Infrastructure landtake</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Potable water consumed and saved</td>
<td>460000.00</td>
<td>569967.15</td>
</tr>
<tr>
<td>Stormwater conveyance and treatment</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Flood protection</td>
<td>-2200.00</td>
<td>-</td>
</tr>
<tr>
<td>Building insulation</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Carbon dioxide reduction</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Other costs and benefits</td>
<td>0.00</td>
<td>0.00</td>
</tr>
</tbody>
</table>

Energy consumed in urban water cycle table

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Conventional Development</th>
<th>Development with SuDS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Energy consumption (kWh/m³)</td>
<td>Emissions (kg CO₂e/m³)</td>
</tr>
<tr>
<td>Water supply acquisition</td>
<td>1.981</td>
<td>1.730</td>
</tr>
<tr>
<td>Water supply conveyance</td>
<td>0.448</td>
<td>0.390</td>
</tr>
<tr>
<td>Water supply distribution</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Stormwater conveyance</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Stormwater treatment</td>
<td>0.00</td>
<td>0.00</td>
</tr>
</tbody>
</table>
2.4. Scenario 2: Development with SuDS

2.4.1. General description

- General description of proposed solution.

  *The selected area is heavily developed, leaving no open spaces where SuDS can be developed. The new infrastructures are being retrofitted in strategic location to collect storm water and reduce the surface runoff produced.*

- Map of these solutions.

- General criteria that have guided the design of drainage infrastructures.

  One of the general criteria used for the SUDS solution in Malta is the stormwater tunnels that have been recently constructed as part of the NFRP project. Around the island a number of tunnels have been constructed to receive stormwater from roads and other public spaces with only limited filtration. Properly implemented SUDS will provide the treatment required so that the excess stormwater will require less treatment after storage and there will be fewer maintenance problems caused by deposition of sediments in the storm tunnels.

  Excess stormwater from this scenario is collected through one of the catchments further down the road. From which it is then directed to a 3.2 km tunnel with a 3m diameter. The tunnel runs from Haz-Zabbar down to Marsascala, where it outflows into the sea.
2.4.2. Drainage infrastructures included in the scenario

- Description of included infrastructures.

Green Roof (extensive) - collects rain water directly on its surface; while enhancing its aesthetical features it reduces runoff volume and attenuates peak flows.

Permeable Pavement - reduces the amount of surface runoff and makes the roads safer during storms while prevents soluble and particulate pollutants from flowing into the sea.

Infiltration Detention Basin - a large pond in a low lying area used to collect the surface runoff water, in which water will slowly filter itself into the ground to recharge the aquifer.

- Design criteria followed in each infrastructure.
  
  o  **Green Roof**

  The required size of a vegetated roof was determined from several factors, including the porosity and hydraulic conductivity of the growing media and the underlying drainage materials.

  Calculations were carried out to ensure that the building will be able to support the additional live and dead structural load and to determine the maximum depth of the vegetated roof system and any needed structural reinforcement.

  The eight different layers were introduced together to protect the roof and maintain a vigorous cover, these are; deck layer, waterproofing layer, insulation layer, root barrier, drainage layer and drainage system, root-permeable filter fabric, growing media and plant cover.

  The drainage layer below the growth media was designed to convey a storm without backing water up to into the growing media. The drainage layer will convey flow to an overflow system such as a traditional rooftop drainage system with inlets set slightly above the elevation of the vegetated roof surface.

  The primary ground cover for this roof is a hardy, low-growing succulent, such as Sedum, that is matched to the local climate conditions and can tolerate the difficult growing conditions found on building rooftops.

  o  **Permeable Pavement**

  The four main site elements, total traffic, in-situ soil strength, environmental elements and the bedding and reservoir layer design were considered in the structural design of permeable pavements.

  Permeable pavement was sized to store the design storm volume in the reservoir layer. The infiltration rate was less than the flow rate through the pavement, therefore underground reservoir storage was required.
Additional pretreatment was introduced since the pavement receives run-on from an adjacent impervious areas.

The thickness of the reservoir layer was determined by runoff storage needs, the infiltration rate of in situ soils, structural requirements of the pavement sub-base and depth to water table and bedrock.

Underdrains were introduced to manage extreme storm events to keep detained storm water from backing up into the permeable pavement.

- **Infiltration Detention Basin**

The anticipated development conditions and drainage area were determined to make sure they are appropriate for an infiltration detention basin application.

The location for the infiltration detention basin was chosen on the site within topographic constraints. The drainage area to the infiltration detention basin was determined and the required water quality volume was calculated.

Evaluation of the hydrology of the contributing drainage area was carried out to determine peak rates of runoff.

- **Summary of values included in the DST.**

<table>
<thead>
<tr>
<th>Construction and maintenance</th>
<th>Scenario 2 : Green Roof</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Area of Drainage 1,000m²</td>
<td>Total Area of Green Roof 1,000 m²</td>
</tr>
<tr>
<td>Unitary construction cost (€/unit)</td>
<td>145.00</td>
</tr>
<tr>
<td>Unitary energy consumption during construction (kWh/unit)</td>
<td>93.28</td>
</tr>
<tr>
<td>Unitary CO₂ emissions during construction (kgCO₂/unit)</td>
<td>28.11</td>
</tr>
<tr>
<td>Unitary maintenance cost (€/year/unit)</td>
<td>10</td>
</tr>
<tr>
<td>Unitary energy consumption during maintenance (kWh/year/unit)</td>
<td>*</td>
</tr>
<tr>
<td>Unitary CO₂ emissions during maintenance (kgCO₂/year/unit)</td>
<td>*</td>
</tr>
<tr>
<td>Lifespan (years)</td>
<td>40</td>
</tr>
<tr>
<td>Unitary construction cost (€/m)</td>
<td>NA</td>
</tr>
</tbody>
</table>

*No Local Values obtained yet.

<table>
<thead>
<tr>
<th>Construction and maintenance</th>
<th>Scenario 2 : Permeable Asphalt</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lifespan (years)</td>
<td>40</td>
</tr>
<tr>
<td>Unitary construction cost (€/m)</td>
<td>NA</td>
</tr>
<tr>
<td>Scenario: Infiltration Detention Basin</td>
<td></td>
</tr>
<tr>
<td>----------------------------------------</td>
<td>------------------</td>
</tr>
<tr>
<td>Total Area of Drainage: 42,049 m²</td>
<td>Total Area of Infiltration Detention Basin: 770 m³</td>
</tr>
<tr>
<td>Unitary construction cost (€/unit)</td>
<td>22.00</td>
</tr>
<tr>
<td>Unitary energy consumption during construction (kWh/unit)</td>
<td>25.52</td>
</tr>
<tr>
<td>Unitary CO₂ emissions during construction (kgCO₂/unit)</td>
<td>7.5</td>
</tr>
<tr>
<td>Unitary maintenance cost (€/year/unit)</td>
<td>0.5</td>
</tr>
<tr>
<td>Unitary energy consumption during maintenance (kWh/year/unit)</td>
<td>0.0039</td>
</tr>
<tr>
<td>Unitary CO₂ emissions during maintenance (kgCO₂/year/unit)</td>
<td>0.001</td>
</tr>
</tbody>
</table>

*No Local Values obtained yet.*
Process followed to estimate construction and maintenance costs.

The unitary cost for each infrastructure was estimated from first principles. A summary of the unitary cost for construction and maintenance is shown below:

<table>
<thead>
<tr>
<th>Ref.</th>
<th>TYPE</th>
<th>UNIT</th>
<th>Construction /EURO</th>
<th>Maintenance /EURO per year</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>GREEN ROOF</td>
<td>per m²</td>
<td>€ 203.26</td>
<td>€ 12.00</td>
</tr>
<tr>
<td>2</td>
<td>PERMEABLE ASPHALT</td>
<td>per m²</td>
<td>€ 229.57</td>
<td>€ 2.75</td>
</tr>
<tr>
<td>3</td>
<td>PERMEABLE PASSAGES</td>
<td>per m²</td>
<td>€ 60.00</td>
<td>€ 1.00</td>
</tr>
<tr>
<td>4</td>
<td>DETENTION BASIN</td>
<td>per m²</td>
<td>€ 25.00</td>
<td>€ 0.50</td>
</tr>
</tbody>
</table>

Process followed to estimate energy consumed and emissions during construction and maintenance.

Several attempts were made to estimate the energy consumed and emissions during construction and maintenance. However, there is no data available for Malta to carry out such calculations.

2.4.3. Water reuse

This part should be complete if the corresponding tab has been completed in the DST.

The water reused in Scenario 2 is 0 m³ as none of the infrastructures proposed has the capacity to store storm water for reuse.

Description of data included in this tab. How have they been obtained?

Not Applicable

If applicable, comparison between real data available and results obtained with the estimation panel.

Not Applicable

Global results obtained in this tab.

Not Applicable
2.4.4. Stormwater runoff

- Description of the hydraulic model used to analyze runoff.

> The catchment areas around the site in question were identified and divided into 3 sections: Agricultural areas, Built-Up areas and Asphalted areas. The Discharge Coefficients for each area were applied for Agricultural areas $\psi = 0.3$, Built-Up areas $\psi = 0.7$ and for Asphalted areas $\psi = 0.9$. The cumulative impermeable area was then calculated.

- Comparison between hydraulic model results and runoff results obtained with the estimation panel.

> The results obtained cannot be compared with the default values as the discharge coefficients have already been applied to the value for the drainage area inputted.

- Global results obtained in this tab.

> The total runoff volume obtained in the storm water runoff tab is 25720 m$^3$

2.4.5. Conveyance and treatment

> This tab was not completed as in Malta storm water is neither pumped nor treated before it is released into the environment.

- Description of data included in this tab. How have they been obtained?

> Not Applicable

- If applicable, comparison between real data available and results obtained with the estimation panel.

> Not Applicable

- Global results obtained in this tab

> Not Applicable

2.4.6. Water quality

- Qualitative water quality results included in this tab.

> No water quality tests were carried out, the runoff catchment characteristics were assumed to be from a commercial zone as it is the land use which produces the worst runoff quality. The sensitivity of the receiving water was assumed to be low as storm water is discharged in open waters. The resultant average water quality for this scenario is medium.

- Other analysis/data about water quality in this scenario.
No other data was collected on the water quality for this scenario.

2.4.7. Flood protection

This part should be complete if the corresponding tab has been completed in the DST.

*In Malta there is no hydraulic data available for the selected area. The number of flooded households and the average damage per household were estimated for each case*

- Description of the hydraulic model used to obtain flooding areas.
  
  Not Applicable

- Description of the method used to estimate economic consequences of flooding in each case.
  
  Not Applicable

- If applicable, comparison between real data available and results obtained with the estimation panel.
  
  Not Applicable

2.4.8. Building insulation

This part should be complete if the corresponding tab has been completed in the DST.

- Description of data included in this tab. How have they been obtained?
  
  o Roof Data – default values were used.
  
  o Heating and Cooling Systems—the efficiency for the heating and cooling systems is 300%.
  
  o Building use data—information on the occupancy of the school was collected from the school administration.

- If applicable, comparison between real data available and default values used in the estimation panel.
  
  The default value was used as no real data was available.

- Global results obtained in this tab.
  
  o Building insulation benefits – 109.45€/year
  
  o Energy consumption avoided – 679.83kWh/year
  
  o Emissions avoided – 592.81 kg CO\textsubscript{2}/year

2.4.9. Summary

- Please, copy the summary tables obtained in this tab.

  Results Table
### Energy consumed in urban water cycle table

<table>
<thead>
<tr>
<th></th>
<th>Scenario 1: Conventional Development</th>
<th>Scenario 2: Development with SuDS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Energy consumption (kWh/m³)</td>
<td>Emissions (kg CO₂e/m³)</td>
</tr>
<tr>
<td>Water supply acquisition</td>
<td>1.981</td>
<td>1.730</td>
</tr>
<tr>
<td>Water supply conveyance</td>
<td>0.448</td>
<td>0.390</td>
</tr>
<tr>
<td>Water supply distribution</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Stormwater conveyance</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Stormwater treatment</td>
<td>0.00</td>
<td>0.00</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Financial cost</th>
<th>Emissions</th>
<th>Financial cost</th>
<th>Emissions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Construction of infrastructures</td>
<td>452940.00</td>
<td>385933.60</td>
<td>121278.80</td>
<td>21180.00</td>
</tr>
<tr>
<td>Maintenance of infrastructures</td>
<td>3560.00</td>
<td>12.04</td>
<td>3.22</td>
<td>29.27</td>
</tr>
<tr>
<td>Infrastructure landtake</td>
<td>0.00</td>
<td>-</td>
<td>0.00</td>
<td>-</td>
</tr>
<tr>
<td>Potable water consumed and saved</td>
<td>460000.00</td>
<td>569967.15</td>
<td>497419.05</td>
<td>536198.97</td>
</tr>
<tr>
<td>Stormwater conveyance and treatment</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Flood protection</td>
<td>-2200.00</td>
<td>-</td>
<td>-3000.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Building insulation</td>
<td>0.00</td>
<td>0.00</td>
<td>-109.45</td>
<td>-679.83</td>
</tr>
<tr>
<td>Carbon dioxide reduction</td>
<td>-</td>
<td>-</td>
<td>0.00</td>
<td>-88.00</td>
</tr>
<tr>
<td>Other costs and benefits</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
</tbody>
</table>
2.5. RESULTS

2.5.1. Time graphs

- Global time graphs obtained with the DST (graph and tables).

Cost Present Value Time Graph

Energy Emissions Time Graph
CO₂ Emissions Time Graph

- Time graphs obtained with only construction and maintenance.

Cost Present Value Time Graph (Construction and Maintenance only)
Energy Consumption Time Graph (Construction and Maintenance only)

CO₂ Emissions Time Graph (Construction and Maintenance only)
- Time graphs obtained without construction and maintenance.

**Cost Present Value Time Graph (Construction and Maintenance only)**

**Energy Emissions Time Graph (Construction and Maintenance only)**
Explanation and justification of results.

The results above indicate the following:

When considering all the criteria:

- The development with SUDS indicate that the cumulative cost present value is less than that with the conventional development
- Suds are more expensive to maintain.
- Less energy consumption with Suds
- CO2 emissions are less with the introduction of sudS

When considering just the construction and maintenance

- The development with SUDS indicate that the cumulative cost present value is much higher than that with the conventional development
- Less energy consumption with Suds for the first thirty years but will consume more energy with Suds after the 30th year
- CO2 emissions are less with the Suds for the first thirty years.

When considering all the criteria except the construction and maintenance

- The development with SUDS indicate that the cumulative cost present value is less than that with the conventional development
- Less energy consumption with Suds
- CO2 emissions are less with the introduction of sudS

CO2 Emissions Time Graph (Without Construction and Maintenance)
2.5.2. Decision criteria

- Decision criteria chosen. How have they been chosen? Have the stakeholders and managers participated in this choice?

The decision criteria chosen were discussed during the RWGEE meetings. The stakeholders involved in these meetings evaluated the criteria presented and chose the most important criteria for the conventional scenario in Haz-Zabbar. The following are the chosen criteria:

- Total construction and maintenance cost (€)
- Building insulation benefits (€/year)
- Total emissions in construction and maintenance (kg CO$_2$e)
- Global outflow water quality
- Building insulation energy saved (kWh/year)
- Volume of runoff produced (m$^3$/year)
- Flood protection benefits (€/year)
- Nutrients removal efficiency

The above criteria are those considered to be most important and most effective in a storm water design system.

- Weights used for each criterion.

  Total construction and maintenance cost (€) (30%)
  Building insulation benefits (€/year) (10%)
  Total emissions in construction and maintenance (kg CO$_2$e) (5%)
  Global outflow water quality (20%)
  Building insulation energy saved (kWh/year) (5%)
  Volume of runoff produced (m$^3$/year) (20%)
  Flood protection benefits (€/year) (5%)
  Nutrients removal efficiency (5%)
Minimum and maximum values considered in each criterion.

<table>
<thead>
<tr>
<th>Criterion</th>
<th>Minimum Value</th>
<th>Maximum Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total construction and maintenance cost</td>
<td>4.43e+06€</td>
<td>0€</td>
</tr>
<tr>
<td>Building insulation benefits</td>
<td>0 €/year</td>
<td>556.28 €/year</td>
</tr>
<tr>
<td>Total emissions in construction and maintenance</td>
<td>1.4304e+06 kg CO$_2$e</td>
<td>0 kg CO$_2$e</td>
</tr>
<tr>
<td>Global outflow water quality</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Building insulation energy saved</td>
<td>0 kWh/year</td>
<td>3455.1 kWh/year</td>
</tr>
<tr>
<td>Volume of runoff produced</td>
<td>28318 m$^3$/year</td>
<td>0 m$^3$/year</td>
</tr>
<tr>
<td>Flood protection benefits</td>
<td>0 €/year</td>
<td>5000 €/year</td>
</tr>
<tr>
<td>Nutrients removal efficiency</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

2.5.3. Multi-criteria analysis results

- Circular results per scenario (graphs and table).

![Graph showing circular results per scenario]

Scenario 1: Conventional Development
Scenario 2: Development with SUDS

- Global results (graph and table).
• Explanation and justification of results.

The above graphs indicate that the benefits with the development with suds are much more than those with the conventional method.

The significant difference lies in the outflow water quality, which is considered as a very important aspect.

Some benefits which are negligent in the conventional method can be clearly identified in the results of the graphs with the introduction of Suds.

2.6. CONCLUSIONS

• Final conclusions to support the decision-making process in this urban area.
  o The results indicate that the decision-making process give the user a better idea of the benefits that one system can have over the other system. Without this tool the decisions are normally taken instantaneous and just on mental reflections.
  o With the support of the tool, the whole process for solving the problem is followed by defining the problem, identifying the limiting factors, developing potential alternatives, analyzing them and select the best alternative.
  o In the particular case analysed it indicates that although with a limited amount of benefit, since it is a retro fitted system, the system with Suds still gives more benefits than the conventional system. Without this process, one may easily state that since it is a retro fitted system, the conventional system will be better but with the help of the tool, it clearly indicates otherwise.

• Benefits achieved with SuDS solution.

The benefits achieved with the SuDS solution are the following:
  o Better water quality at the outflow
  o Protection of receiving bodies
  o Re use of stormwater
  o Reduction in water consumption
  o Support flood management activities to protect properties from flooding
3. PILOT CASE 2: NEW DEVELOPMENT AREA

3.1. GENERAL DESCRIPTION

- Location map of this area.

- Main characteristics: number of households, population, drainage area, drainage system...

  The area selected for the new development consists mainly of undisturbed land. There is no stormwater system in use as most of the roads have not yet been formed.

<table>
<thead>
<tr>
<th></th>
<th>Number of Residents</th>
<th>Number of Households</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ħaż-Żabbar</td>
<td>12219</td>
<td>5649</td>
</tr>
<tr>
<td>New Development within Selected Area</td>
<td>627</td>
<td>290</td>
</tr>
</tbody>
</table>

*according to electoral register
- Main problems/issues to be solved. Potential for improvement of stormwater management.

  Rainfall in Malta is different from the other countries in Europe; we usually have flash flooding.

  The size of household cisterns.

  Household roof drains illegally connected to the sewage system.

  Stormwater is not always good for re-use as it may be contaminated.

  The use of potable water for irrigation.

  The entity to be responsible for the maintenance of the SuDS is to be identified.

- Expected energy benefits with SuDS option.

  Green Roof (Extensive) provides insulation and can lower heating and cooling costs for the building. Reduced the amount of potable water which would be needed for irrigation.

  Household rain harvesting system reduces the amount of potable water by reusing storm water for flushing toilets, washing machines and irrigation hence reducing energy for its production and transportation.

### 3.2. General Model Data

- Description of data included in this menu. How have they been obtained?
A. The Country where the urban area analysed is located is Malta.

B. Economic units: The national monetary units for Malta are Euro.

C. Electricity price: Cost of electricity in the analysed urban area is €0.162 exclusive of VAT. This is the Non-Residential rate per kWh obtained from Enemalta website.

D. Electricity emissions: The default values (values of 2010) of the CO₂ emissions produced per KWh of electricity consumption was used as there is no data available for Malta.

E. Period of analysis: 40 years return period was considered for Malta.

F. Economic discount rate: The economic discount rate used for Malta is 3%.

G. Rainfall distribution: The monthly average rainfall in the urban area was obtained from FAO (2006) Malta, Water Resources Review
H. Temperatures distribution: The hourly temperature for 365 consecutive days was obtained for the Malta from Meteorological Office. The average daily temperatures variation in summer and in winter in the urban area were then extracted from this data.

I. Flood events: For these scenarios the return periods of considered flood events is considered to be 10 years.
• If applicable, comparison between real data available and default values proposed in this menu.

This is not applicable.
3.3. SCENARIO 3: CONVENTIONAL DEVELOPMENT

3.3.1. General description

- General description of proposed solution.

*The proposed storm water solution for the new area using conventional systems - storm water flowing on the surface of residential roads is collected via gratings and conveyed through underground pipes and directed to a reservoir. The collected storm water can be reused for irrigation. The overflow of the reservoir will discharged into the Marsascala basin.*

When one comes to start planning a new projects, cost is one of detrimental factors. The approach we used for comparing the performance of these two scenarios is ‘limited by budget’ approach. We have chosen infrastructures that would have the same cost in the period of analysis. The question we asked is; ‘How much can we undertake for a fixed budget?’ This results of this approach would show the advantages/disadvantages of using SuDS over the conventional system when the cost for both system is the same.

- Map of these solutions.

- General criteria that have guided the design of drainage infrastructures.
3.3.2. Drainage infrastructures included in the scenario

- Description of included infrastructures.
  - Conventional Pipe Network System - It collects urban storm water and conveys it as rapidly as possible to the outflow point avoiding flooding in streets and houses. This will be a separated system, there will be a separate system for waste water.
  - Reservoir – it is used to capture and store storm water collected through the pipe network system. Stored water can be reused for irrigation of public landscaped areas.
  - Conventional Roof – the roof is the covering on the most upper part of the building, protecting it from rainfall. It is impervious, and conveys urban storm water very quickly.
  - Standard pavement – these are impervious and they do not allow water to infiltrate into the subsoil. Surface runoff water is collected through the conventional pipe network system.

- Design criteria followed in each infrastructure.

  The catchment areas around the site in question were identified and divided into 3 sections: Agricultural areas, Built-Up areas, and Asphalted areas (Discharge Coefficients, ψ = 0.3, 0.7, 0.9 respectively). The cumulative impermeable area is then calculated. The flow, Q, to be catered for is therefore identified. uPVC was identified as the material to be used for the pipes. According to the diameter and gradient of the proposed pipes, the pipe capacity is generated using Mannings formula and this should be greater than the flow Q. Flow Q of the rainfall was generated from the rain intensity. From statistical data, it had been established that the intensity of a 15 minute storm which occurs once every year (1 in 1 year) which is used locally for such calculations for normal stormwater networks in roads. This amounts to a value of 179 l/s/ha. The water collected in the pipe network will be stored in the reservoir at the lowest point. The storm water may be reused for irrigating purposes, the overflow of the reservoir will discharge into the valley.

- Summary of values included in the DST.

<table>
<thead>
<tr>
<th>Construction and maintenance Scenario 3 Pipe Network</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Total Area of Drainage</strong>: 37,368m²</td>
</tr>
<tr>
<td><strong>Total Length of Pipe Network</strong>: 1,120m</td>
</tr>
<tr>
<td><strong>Unitary construction cost (€/unit)</strong></td>
</tr>
<tr>
<td><strong>Unitary energy consumption during construction (kWh/unit)</strong></td>
</tr>
<tr>
<td><strong>Unitary CO₂ emissions during construction (kgCO₂/unit)</strong></td>
</tr>
<tr>
<td><strong>Unitary maintenance cost (€/year/unit)</strong></td>
</tr>
<tr>
<td>Scenario</td>
</tr>
<tr>
<td>----------</td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>

**Construction and maintenance**

**Scenario 3 Structural Detention Facility**

<table>
<thead>
<tr>
<th>Unitary construction cost (€/unit)</th>
<th>400.00</th>
<th>207.00</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unitary energy consumption during construction (kWh/unit)</td>
<td>849.29</td>
<td>*</td>
</tr>
<tr>
<td>Unitary CO₂ emissions during construction (kgCO₂/unit)</td>
<td>269</td>
<td>*</td>
</tr>
<tr>
<td>Unitary maintenance cost (€/year/unit)</td>
<td>1.5</td>
<td>1</td>
</tr>
<tr>
<td>Unitary energy consumption during maintenance (kWh/year/unit)</td>
<td>0.00</td>
<td>*</td>
</tr>
<tr>
<td>Unitary CO₂ emissions during maintenance (kgCO₂/year/unit)</td>
<td>0.00</td>
<td>*</td>
</tr>
<tr>
<td>Lifespan (years)</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>Unitary construction cost (€/m)</td>
<td>NA</td>
<td>NA</td>
</tr>
</tbody>
</table>

**Construction and maintenance**

**Scenario 3 Conventional Roof**

<table>
<thead>
<tr>
<th>Unitary construction cost (€/unit)</th>
<th>60.00</th>
<th>100.00</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unitary energy consumption during construction (kWh/unit)</td>
<td>123.07</td>
<td>*</td>
</tr>
<tr>
<td>Unitary CO₂ emissions during construction (kgCO₂/unit)</td>
<td>37.29</td>
<td>*</td>
</tr>
<tr>
<td>Unitary maintenance cost (€/year/unit)</td>
<td>0.4</td>
<td>0.5</td>
</tr>
<tr>
<td>Unitary energy consumption during maintenance (kWh/year/unit)</td>
<td>0.00</td>
<td>*</td>
</tr>
<tr>
<td>Unitary CO₂ emissions during maintenance (kgCO₂/year/unit)</td>
<td>0.00</td>
<td>*</td>
</tr>
<tr>
<td>Lifespan (years)</td>
<td>23</td>
<td>40</td>
</tr>
<tr>
<td>Unitary construction cost (€/m)</td>
<td>NA</td>
<td>NA</td>
</tr>
</tbody>
</table>

**Construction and maintenance**

**Scenario 3 Standard Pavement**

<table>
<thead>
<tr>
<th>Unitary construction cost (€/unit)</th>
<th>50.00</th>
<th>89.00</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unitary energy consumption during construction (kWh/unit)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unitary CO₂ emissions during construction (kgCO₂/unit)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unitary maintenance cost (€/year/unit)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unitary energy consumption during maintenance (kWh/year/unit)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unitary CO₂ emissions during maintenance (kgCO₂/year/unit)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lifespan (years)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unitary construction cost (€/m)</td>
<td>NA</td>
<td>NA</td>
</tr>
</tbody>
</table>
Process followed to estimate construction and maintenance costs.

The unitary cost for each infrastructure was estimated from first principles a summary of the unitary cost for construction and maintenance is shown below;

<table>
<thead>
<tr>
<th>Ref.</th>
<th>TYPE</th>
<th>UNIT</th>
<th>CONSTRUCTION /EURO</th>
<th>MAINTENANCE /EURO per year</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>PIPE NETWORK (small area)</td>
<td>per m run</td>
<td>€ 219.00</td>
<td>€ 2.00</td>
</tr>
<tr>
<td>2</td>
<td>RESERVOIR</td>
<td>per m³</td>
<td>€ 207.00</td>
<td>€ 1.00</td>
</tr>
<tr>
<td>3</td>
<td>STANDARD PAVEMENT</td>
<td>per m²</td>
<td>€ 100.00</td>
<td>€ 0.50</td>
</tr>
<tr>
<td>4</td>
<td>CONVENTIONAL ROOF</td>
<td>per m²</td>
<td>€ 89.00</td>
<td>€ 0.45</td>
</tr>
</tbody>
</table>

Process followed to estimate energy consumed and emissions during construction and maintenance.

Several attempts were made to estimate the energy consumed and emissions during construction and maintenance. However there is no data available for Malta to carry out such calculations.

3.3.3. Water reuse

This part should be complete if the corresponding tab has been completed in the DST.

The water reused in Scenario 3 is $0 \text{m}^3$ as no information was available on the monthly water demand.

Description of data included in this tab. How have they been obtained?
Not Applicable

- If applicable, comparison between real data available and results obtained with the estimation panel.
  
  Not Applicable

- Global results obtained in this tab.
  
  Not Applicable

3.3.4. Stormwater runoff

- Description of the hydraulic model used to analyze runoff.
  
  The catchment areas around the site in question were identified and divided into 3 sections: Agricultural areas, Built-Up areas and Asphalted areas. The Discharge Coefficients for each area were applied for Agricultural areas $\psi = 0.3$, Built-Up areas $\psi = 0.7$ and for Asphalted areas $\psi = 0.9$. The cumulative impermeable area was then calculated.

- Comparison between hydraulic model results and runoff results obtained with the estimation panel.
  
  The results obtained cannot be compared with the default values as the discharge coefficients have already been applied to the value for the drainage area inputted.

- Global results obtained in this tab.
  
  The total runoff volume obtained in the storm water runoff tab is $21897\text{m}^3$

3.3.5. Conveyance and treatment

This tab was not completed as in Malta storm water is neither pumped nor treated before it is released into the environment.

- Description of data included in this tab. How have they been obtained?
  
  Not Applicable

- If applicable, comparison between real data available and results obtained with the estimation panel.
  
  Not Applicable

- Global results obtained in this tab
  
  Not Applicable
3.3.6. Water quality

- Qualitative water quality results included in this tab.

  
  No water quality tests were carried out, the runoff catchment characteristics were assumed to be from a commercial zone as it is the land use which produces the worst runoff quality. The sensitivity of the receiving water was assumed to be low as storm water is discharged in open waters.

- Other analysis/data about water quality in this scenario.

  No other data was collected on the water quality for this scenario.

3.3.7. Flood protection

This part should be complete if the corresponding tab has been completed in the DST.

  In Malta there is no hydraulic data available for the selected area. The number of flooded households and the average damage per household were estimated for each case.

- Description of the hydraulic model used to obtain flooding areas.

  Not Applicable

- Description of the method used to estimate economic consequences of flooding in each case.

  Not Applicable

- If applicable, comparison between real data available and results obtained with the estimation panel.

  Not Applicable

3.3.8. Building insulation

This part should be complete if the corresponding tab has been completed in the DST.

- Description of data included in this tab. How have they been obtained?

- If applicable, comparison between real data available and default values used in the estimation panel.

- Global results obtained in this tab.
3.3.9. Summary

- Please, copy the summary tables obtained in this tab.

**Results Table**

<table>
<thead>
<tr>
<th>Construction of infrastructures</th>
<th>Financial cost</th>
<th>Energy consumption</th>
<th>Emissions</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>820472.00</td>
<td>1230547.50</td>
<td>383098.12</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Maintenance of infrastructures</th>
<th>Financial cost</th>
<th>Energy consumption</th>
<th>Emissions</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>5107.00</td>
<td>20.77</td>
<td>5.54</td>
</tr>
</tbody>
</table>

| Infrastructure landtake         | 0.00           | -                  | -         |

<table>
<thead>
<tr>
<th>Potable water consumed and saved</th>
<th>Financial cost</th>
<th>Energy consumption</th>
<th>Emissions</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>598000.00</td>
<td>740957.30</td>
<td>646644.77</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Stormwater conveyance and treatment</th>
<th>Financial cost</th>
<th>Energy consumption</th>
<th>Emissions</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
</tbody>
</table>

| Flood protection                    | -2800.00       | -                  | -         |

| Building insulation                 | 0.00           | 0.00               | 0.00      |

| Carbon dioxide reduction            | -              | -                  | -         |

| Other costs and benefits            | 0.00           | 0.00               | 0.00      |

**Energy consumed in urban water cycle table**

<table>
<thead>
<tr>
<th>Water supply acquisition</th>
<th>Energy consumption (kWh/m³)</th>
<th>Emissions (kg CO₂e/m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water supply conveyance</td>
<td>0.448</td>
<td>0.390</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Water supply distribution</th>
<th>Energy consumption (kWh/m³)</th>
<th>Emissions (kg CO₂e/m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stormwater conveyance</td>
<td>0.00</td>
<td>0.00</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Stormwater treatment</th>
<th>Energy consumption (kWh/m³)</th>
<th>Emissions (kg CO₂e/m³)</th>
</tr>
</thead>
</table>
3.4. Scenario 4: Development with SuDS

3.4.1. General description

- General description of proposed solution.

  The proposed solution would prevent the new area from flooding while at the same time creating a separate drainage network. For the new area a number of SuDS shall be incorporated in the design and construction of the development. This will result in better planning and maximising the benefits of SuDS. A large part of the roof area of a residential block will be covered in green roof, while the paving of the recreational area will be permeable. Runoff water from the secondary roads is directed towards the main road where filter drains shall be constructed on both sides, water will then flow through a bio retention area and collected in a retention basin at the lowest point of the area.

- Map of these solutions.

- General criteria that have guided the design of drainage infrastructures.

One of the general criteria used for the SUDS solution in Malta is the stormwater tunnels that have been recently constructed as part of the NFRP project. Around the island a number of tunnels have been constructed to receive stormwater from roads and other public spaces with only limited filtration. Properly implemented SUDS will provide the treatment required so that the excess stormwater will require less treatment after storage and there will be fewer maintenance problems caused by deposition of sediments in the storm tunnels.
Excess stormwater from this scenario is collected through a number of the catchments further down the road. From which it is then directed to a 3.2 km tunnel with a 3m diameter. The tunnel runs from Haz-Zabbar down to Marsascala, where it outflows into the sea.

### 3.4.2. Drainage infrastructures included in the scenario

- **Description of included infrastructures.**
  - **Green Roof (extensive)** - collects rain water directly on its surface; while enhancing its aesthetical features it reduces runoff volume and attenuates peak flows.
  - **Permeable Pavement** - reduces the amount of surface runoff and makes the roads safer during storms while prevents soluble and particulate pollutants from flowing into the sea.
  - **Bio retention areas** - reduces storm water volume during storms while at the same time it increases biodiversity in the area while providing landscaping features.
  - **Filter Drains** - to be constructed along the main road, these are gravel filled trenches that collect, treat and move water. The trench is filled with free draining gravel and often has a perforated pipe in the bottom to collect the water.
  - **Retention Ponds** - to be incorporated in the landscaping proposed within the Landscaping area, to collect storm water in winter and as a dry landscaping feature in the dry summer months.

- **Design criteria followed in each infrastructure.**
  - **Green Roof**
    
    The required size of a vegetated roof was determined from several factors, including the porosity and hydraulic conductivity of the growing media and the underlying drainage materials.

    The eight different layers were introduced together to protect the roof and maintain a vigorous cover, these are; deck layer, waterproofing layer, insulation layer, root barrier, drainage layer and drainage system, root-permeable filter fabric, growing media and plant cover.

    The drainage layer below the growth media was designed to convey a storm without backing water up to into the growing media. The drainage layer will convey flow to an overflow system such as a traditional rooftop drainage system with inlets set slightly above the elevation of the vegetated roof surface.

    The primary ground cover for this roof is a hardy, low-growing succulent, such as Sedum, that is matched to the local climate conditions and can tolerate the difficult growing conditions found on building rooftops.

    **Permeable Pavement**
The four main site elements, total traffic, in-situ soil strength, environmental elements and the bedding and reservoir layer design were considered in the structural design of permeable pavements.

Permeable pavement was sized to store the design storm volume in the reservoir layer. The infiltration rate was less than the flow rate through the pavement, therefore underground reservoir storage was required.

Pretreatment was not necessary, since the surface acts as pretreatment to the reservoir layer below.

The thickness of the reservoir layer was determined by runoff storage needs, the infiltration rate of in situ soils, structural requirements of the pavement sub-base and depth to water table and bedrock.

Underdrains were introduced to manage extreme storm events to keep detained storm water from backing up into the permeable pavement.

- Bio Retention Area

Bioretention areas are designed to filter the treatment volume into the underlying gravel bed and collector pipe system.

The elevation of the overflow structure was designed to be above the elevation of the bioretention bed. If the filter soil remains constantly wet, anaerobic conditions will develop, which will kill the plants and cause iron phosphates which have been previously captured to break down and escape into the effluent.

Geomembrane was chosen as an impermeable liner, a suitable geotextile fabric shall be placed below and on the top of the membrane for puncture protection.

- Filter Drain

The geometry of the filter strip; the length, width and slope were considered when designing the filter drain with an optimal performance.

A level spreader was designed to ensure that runoff fills the spreader evenly and flows over the level lip as uniformly as possible.

A pervious berm may be installed to force ponding. An armoured overflow should be provided to allow larger storms to pass without overtopping the berm.

A filter strip will be densely vegetated with a mix of erosion resistant plant species that effectively bind the soil. The selection of plants is based on their compatibility with climate conditions, soils and topography and their ability to tolerate urban stresses from pollutants, variable soil moisture conditions and ponding fluctuations.

- Retention Pond
The topographic condition were investigated and appropriate components for this area were selected to ensure long-term operation.

The retention area is designed to filter the treatment quantity into the underlying soil strata.

Elevations were carefully worked out to assure that the desired amount runoff will flow into this area and pool at no more than the maximum design depth.

Different species were chosen to insure diversity, in addition to reducing the potential for monoculture mortality concerns, a diversity of trees and shrubs with differing rates of transpiration may ensure a more constant rate of evapotranspiration and nutrient and pollutant uptake throughout the growing season.

- Summary of values included in the DST.

<table>
<thead>
<tr>
<th>Construction and maintenance</th>
<th>Scenario 4 Green Roof</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Area of Drainage</td>
<td>3,400m²</td>
</tr>
<tr>
<td>Total Area of Green Roof</td>
<td>3,000m²</td>
</tr>
<tr>
<td>Unitary construction cost (€/unit)</td>
<td>145.00</td>
</tr>
<tr>
<td>Unitary energy consumption during construction (kWh/unit)</td>
<td>93.28</td>
</tr>
<tr>
<td>Unitary CO₂ emissions during construction (kgCO₂/unit)</td>
<td>28.11</td>
</tr>
<tr>
<td>Unitary maintenance cost (€/year/unit)</td>
<td>10.00</td>
</tr>
<tr>
<td>Unitary energy consumption during maintenance (kWh/year/unit)</td>
<td>0.00</td>
</tr>
<tr>
<td>Unitary CO₂ emissions during maintenance (kgCO₂/year/unit)</td>
<td>0.00</td>
</tr>
<tr>
<td>Lifespan (years)</td>
<td>40</td>
</tr>
<tr>
<td>Unitary construction cost (€/m)</td>
<td>NA</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Construction and maintenance</th>
<th>Scenario 4 Permeable Pavement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Area of Drainage</td>
<td>1,780m²</td>
</tr>
<tr>
<td>Total Area of Permeable Pavement</td>
<td>1,780m²</td>
</tr>
<tr>
<td>Unitary construction cost (€/unit)</td>
<td>60.00</td>
</tr>
<tr>
<td>Unitary energy consumption during construction (kWh/unit)</td>
<td>92.18</td>
</tr>
<tr>
<td>Unitary CO₂ emissions during construction (kgCO₂/unit)</td>
<td>29.17</td>
</tr>
<tr>
<td>Unitary maintenance cost (€/year/unit)</td>
<td>1</td>
</tr>
<tr>
<td>Unitary energy consumption during maintenance (kWh/year/unit)</td>
<td>0.0014</td>
</tr>
<tr>
<td>Unitary CO₂ emissions during maintenance (kgCO₂/year/unit)</td>
<td>0.0004</td>
</tr>
<tr>
<td>Lifespan (years)</td>
<td>30</td>
</tr>
<tr>
<td>Construction and maintenance</td>
<td>Scenario 4 Filter Drain</td>
</tr>
<tr>
<td>-------------------------------</td>
<td>-------------------------</td>
</tr>
<tr>
<td>Total Area of Drainage-33,202m²</td>
<td>Total Area of Filter Drain-97m³</td>
</tr>
<tr>
<td>Unitary construction cost (€/unit)</td>
<td>175.00</td>
</tr>
<tr>
<td>Unitary energy consumption during construction (kWh/unit)</td>
<td>101.28</td>
</tr>
<tr>
<td>Unitary CO₂ emissions during construction (kgCO₂/unit)</td>
<td>31.99</td>
</tr>
<tr>
<td>Unitary maintenance cost (€/year/unit)</td>
<td>0.90</td>
</tr>
<tr>
<td>Unitary energy consumption during maintenance (kWh/year/unit)</td>
<td>6.883</td>
</tr>
<tr>
<td>Unitary CO₂ emissions during maintenance (kgCO₂/year/unit)</td>
<td>1.813</td>
</tr>
<tr>
<td>Lifespan (years)</td>
<td>30</td>
</tr>
<tr>
<td>Unitary construction cost (€/m)</td>
<td>NA</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Construction and maintenance</th>
<th>Scenario 4 Bio retention Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Area of Drainage-78m²</td>
<td>Total Area of Bio Retention Area-78m²</td>
</tr>
<tr>
<td>Unitary construction cost (€/unit)</td>
<td>75.00</td>
</tr>
<tr>
<td>Unitary energy consumption during construction (kWh/unit)</td>
<td>137.13</td>
</tr>
<tr>
<td>Unitary CO₂ emissions during construction (kgCO₂/unit)</td>
<td>42.32</td>
</tr>
<tr>
<td>Unitary maintenance cost (€/year/unit)</td>
<td>8.00</td>
</tr>
<tr>
<td>Unitary energy consumption during maintenance (kWh/year/unit)</td>
<td>0.0987</td>
</tr>
<tr>
<td>Unitary CO₂ emissions during maintenance (kgCO₂/year/unit)</td>
<td>0.026</td>
</tr>
<tr>
<td>Lifespan (years)</td>
<td>30</td>
</tr>
<tr>
<td>Unitary construction cost (€/m)</td>
<td>NA</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Construction and maintenance</th>
<th>Scenario 4 Retention Pond</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Area of Drainage-33,685m²</td>
<td>Total Volume of Retention Pond-560m³</td>
</tr>
<tr>
<td>Unitary construction cost (€/unit)</td>
<td>45.00</td>
</tr>
<tr>
<td>Unitary energy consumption during construction (kWh/unit)</td>
<td>36.84</td>
</tr>
<tr>
<td>Unitary CO₂ emissions during construction (kgCO₂/unit)</td>
<td>11.10</td>
</tr>
</tbody>
</table>
- Process followed to estimate construction and maintenance costs.

The unitary cost for each infrastructure was estimated from first principles a summary of the unitary cost for construction and maintenance is shown below;

<table>
<thead>
<tr>
<th>REF.</th>
<th>TYPE</th>
<th>UNIT</th>
<th>CONSTRUCTION /EURO</th>
<th>MAINTENANCE /EURO per year</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>GREEN ROOF</td>
<td>per m²</td>
<td>€ 203.00</td>
<td>€ 12.00</td>
</tr>
<tr>
<td>2</td>
<td>PERMEABLE PAVEMENT</td>
<td>per m²</td>
<td>€ 80.00</td>
<td>€ 2.50</td>
</tr>
<tr>
<td>3</td>
<td>FILTER DRAIN</td>
<td>per m run</td>
<td>€ 109.00</td>
<td>€ 3.00</td>
</tr>
<tr>
<td>4</td>
<td>BIORETENTION AREA</td>
<td>per m²</td>
<td>€ 98.00</td>
<td>€ 10.00</td>
</tr>
<tr>
<td>5</td>
<td>RETENTION POND</td>
<td>per m²</td>
<td>€ 66.00</td>
<td>€ 2.50</td>
</tr>
</tbody>
</table>

- Process followed to estimate energy consumed and emissions during construction and maintenance.

Several attempts were made to estimate the energy consumed and emissions during construction and maintenance. However there is no data available for Malta to carry out such calculations.

3.4.3. Water reuse

This part should be complete if the corresponding tab has been completed in the DST.

The water reused in Scenario 4 is 0m³ as no information was available on the monthly water demand.

- Description of data included in this tab. How have they been obtained?
  
  Not Applicable

- If applicable, comparison between real data available and results obtained with the estimation panel.
  
  Not Applicable

- Global results obtained in this tab.
Not Applicable

3.4.4. Stormwater runoff

- Description of the hydraulic model used to analyze runoff.

  The catchment areas around the site in question were identified and divided into 3 sections: Agricultural areas, Built-Up areas and Asphalted areas. The Discharge Coefficients for each area were applied for Agricultural areas $\psi = 0.3$, Built-Up areas $\psi = 0.7$ and for Asphalted areas $\psi = 0.9$. The cumulative impermeable area was then calculated.

- Comparison between hydraulic model results and runoff results obtained with the estimation panel.

  The results obtained cannot be compared with the default values as the discharge coefficients have already been applied to the value for the drainage area inputted.

- Global results obtained in this tab.

  The total runoff volume obtained in the storm water runoff tab is $18588 m^3$

3.4.5. Conveyance and treatment

This tab was not completed as in Malta storm water is neither pumped nor treated before it is released into the environment.

- Description of data included in this tab. How have they been obtained?

  Not Applicable

- If applicable, comparison between real data available and results obtained with the estimation panel.

  Not Applicable

- Global results obtained in this tab

  Not Applicable

3.4.6. Water quality

- Qualitative water quality results included in this tab.

  No water quality tests were carried out, the runoff catchment characteristics were assumed to be from a commercial zone as it is the land use which produces the worst runoff quality. The sensitivity of the receiving water was assumed to be low as storm water is discharged in open waters.

- Other analysis/data about water quality in this scenario.
No other data was collected on the water quality for this scenario.

3.4.7. Flood protection

This part should be complete if the corresponding tab has been completed in the DST.

In Malta there is no hydraulic data available for the selected area. The number of flooded households and the average damage per household were estimated for each case.

- Description of the hydraulic model used to obtain flooding areas.
  
  Not Applicable

- Description of the method used to estimate economic consequences of flooding in each case.
  
  Not Applicable

- If applicable, comparison between real data available and results obtained with the estimation panel.
  
  Not Applicable

3.4.8. Building insulation

This part should be complete if the corresponding tab has been completed in the DST.

- Description of data included in this tab. How have they been obtained?
  
  o Roof Data – default values were used.
  o Heating and Cooling Systems—the efficiency for the heating and cooling systems is 300%.
  o Building use data—information on the occupancy of the residential units was assumed.

- If applicable, comparison between real data available and default values used in the estimation panel.
  
  The default value was used as no real data was available.

- Global results obtained in this tab.
  
  o Building insulation benefits – 1130.6€/year
  o Energy consumption avoided – 7022.4kWh/year
  o Emissions avoided – 6123.5kg CO₂/year

3.4.9. Summary

- Please, copy the summary tables obtained in this tab.

  Results Table
### Energy consumed in urban water cycle table

<table>
<thead>
<tr>
<th>Scenario 3: New Area - Conventional Development</th>
<th>Scenario 4: New Area - Development with SuDS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Financial cost</td>
<td>Energy consumption (kWh/m³)</td>
</tr>
<tr>
<td>Construction of infrastructures</td>
<td>820472.00</td>
</tr>
<tr>
<td>Maintenance of infrastructures</td>
<td>5107.00</td>
</tr>
<tr>
<td>Infrastructure landtake</td>
<td>0.00</td>
</tr>
<tr>
<td>Potable water consumed and saved</td>
<td>598000.00</td>
</tr>
<tr>
<td>Stormwater conveyance and treatment</td>
<td>0.00</td>
</tr>
<tr>
<td>Flood protection</td>
<td>-2800.00</td>
</tr>
<tr>
<td>Building insulation</td>
<td>0.00</td>
</tr>
<tr>
<td>Carbon dioxide reduction</td>
<td>-</td>
</tr>
<tr>
<td>Other costs and benefits</td>
<td>0.00</td>
</tr>
</tbody>
</table>

---

**Energy consumed**

- **Water supply acquisition**: 1.981 kWh/m³, 1.730 kg CO₂e/m³
- **Water supply conveyance**: 0.448 kWh/m³, 0.390 kg CO₂e/m³
- **Water supply distribution**: 0.00 kWh/m³, 0.00 kg CO₂e/m³
- **Stormwater conveyance**: 0.00 kWh/m³, 0.00 kg CO₂e/m³
- **Stormwater treatment**: 0.00 kWh/m³, 0.00 kg CO₂e/m³
- **Carbon dioxide reduction**: -938.00 kg CO₂e/m³
3.5. RESULTS

3.5.1. Time graphs

- Global time graphs obtained with the DST (graph and tables).

Cost Present Value Time Graph

Energy Consumption Time Graph
CO₂ Emission Time Graph

- Time graphs obtained with only construction and maintenance.

Cost Present Value Time Graph (Construction and Maintenance only)
Energy Consumed Time Graph (Construction and Maintenance only)

CO₂ Emissions Time Graph (Construction and Maintenance only)
Time graphs obtained without construction and maintenance.

Cost Present Value Time Graph (without Construction and Maintenance)

Energy Consumed Time Graph (without Construction and Maintenance)
Explanation and justification of results.

The results above indicate the following:

When considering all the criteria:

- The development with SUDS indicate that the cumulative cost present value is substantially less than that with the conventional development
- Suds are more expensive to maintain.
- Substantially less energy consumption with Suds
- CO2 emissions are substantially less with the introduction of Suds

When considering just the construction and maintenance

- The development with SUDS indicate that the cumulative cost present value is much higher than that with the conventional development
- Substantially less energy consumption with Suds
- CO2 emissions are substantially less with Suds systems.

When considering all the criteria except the construction and maintenance

- The development with SUDS indicate that the cumulative cost present value is less than that with the conventional development and the benefits increase by time
3.5.2. Decision criteria

- Decision criteria chosen. How have they been chosen? Have the stakeholders and managers participated in this choice?

The decision criteria chosen were discussed during the RWGEE meetings. The stakeholders involved in these meetings evaluated the criteria presented and chose the most important criteria for the conventional scenario in Haz-Zabbar. The following are the chosen criteria:

- Total construction and maintenance cost (€)
- Building insulation benefits (€/year)
- Total emissions in construction and maintenance (kg CO₂e)
- Global outflow water quality
- Building insulation energy saved (kWh/year)
- Volume of runoff produced (m³/year)
- Evaluation of ecosystem service
- Peak outflow rate (m³/s)

The above criteria are those considered to be most important and most effective in a storm water design system.

- Weights used for each criterion.

  - Total construction and maintenance cost (€) (30%)
  - Building insulation benefits (€/year) (10%)
  - Global outflow water quality (20%)
  - Building insulation energy saved (kWh/year) (5%)
  - Volume of runoff produced (m³/year) (25%)
  - Evaluation of ecosystem services (5%)
  - Peak outflow rate (m³/s) (5%)
Minimum and maximum values considered in each criterion.

<table>
<thead>
<tr>
<th>Criterion</th>
<th>Minimum Value</th>
<th>Maximum Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total construction and maintenance cost</td>
<td>2.4304e+06 (€)</td>
<td>0(€)</td>
</tr>
<tr>
<td>Building insulation benefits</td>
<td>0 (€/year)</td>
<td>556.28 (€/year)</td>
</tr>
<tr>
<td>Global outflow water quality</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Building insulation energy saved</td>
<td>0(kWh/year)</td>
<td>3455.1(kWh/year)</td>
</tr>
<tr>
<td>Volume of runoff produced</td>
<td>21897 (m3/year)</td>
<td>0(m3/year)</td>
</tr>
<tr>
<td>Evaluation of ecosystem services</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Peak outflow rate</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

3.5.3. Multi-criteria analysis results

- Circular results per scenario (graphs and table).

Scenario 3: Conventional Development
Scenario 4: Development with SUDS

- Global results (graph and table).
• Explanation and justification of results.

The above graphs indicate that the benefits with the development with suds are much more than those with the conventional method.

The construction and maintenance cost are much less since it is not a retro fitted system.

A significant difference is noted in the outflow water quality, which is considered as a very important aspect.

Building insulation benefits and building insulation energy saving are considerable with the SuDS system which is obviously in existent with the conventional method.

Some benefits which are negligent in the conventional method can be clearly identified in the results of the graphs with the introduction of Suds.

3.6. CONCLUSIONS

• Final conclusions to support the decision-making process in this urban area.

  o The results indicate that the decision-making process give the user a better idea of the benefits that one system can have over the other system. Without this tool the decisions are normally taken instantaneous and just on mental reflections.

  o With the support of the tool, the whole process for solving the problem is followed by defining the problem, identifying the limiting factors, developing potential alternatives, analyzing them and select the best alternative.

  o In the particular case analysed it indicates that although with a limited amount of benefit, since it is a retro fitted system, the system with Suds still gives more benefits than the conventional system. Without this process, one may easily state that since it is a retro fitted system, the conventional system will be better but with the help of the tool, it clearly indicates otherwise.

• Benefits achieved with SuDS solution.

  The benefits achieved with the SuDS solution are the following:

  o Better water quality at the outflow

  o Protection of receiving bodies

  o Re use of stormwater

  o Reduction in water consumption

  o Support flood management activities to protect properties from flooding.
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Improvement of energy efficiency in the water cycle by the use of innovative storm water management in smart Mediterranean cities
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