Ain Shams University
Faculty of Engineering
Department of Architecture

The Study of Water Efficiency for Egyptian Red Sea Resorts

(Water technologies and their impact on the optimal consumption in the operation phase)

Presented by
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Statement

This thesis is submitted to Ain Shams University for the degree of Master of Science in architecture.

The work included in this thesis was accomplished by the author at the department of Architecture Ain Shams University during the period from April 2011 to June 2013

No part of this thesis has been submitted for a degree or a qualification in any other university or institute.

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(Water technologies and their impact on the optimal consumption in the operation phase).

Date:
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بسم الله الرحمن الرحيم

" وَجَعَلْنَا مِنَ الْمَاءِ كُلَّ شَيْءٍ حَيٍّ "
الأنبياء : 30

"And we have made from water every living thing"
Al-Anbiya': 30

" وَأَنْزَلْنَا مِنَ السَّمَاءِ مَاءً بِقَدَرٍ "
المؤمنون : 18

"And we sent down from the sky water (rain) in (due) measure"
Al-Mu'minun: 18

صدق الله العظيم

قال النبي محمد (عليه الصلاة و السلام):

" لا تسرف فى الماء ولو كنت على طرف نهر جار " رواه ابن ماجه عن ابن عمر

"Do not waste water even if you were at a running stream"

Prophet Muhammad (peace and blessings be upon him) said, Narrated by Ibn Majah from Ibn Umar

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Summary

Water is becoming scarce not only in arid and drought prone areas, but also in regions where rainfall is relatively abundant. In water scarce regions, as is the case for the Middle East and North Africa regions, not only is the potential water availability in these regions low but that sustaining an increased demand requires innovative approaches to cope with water scarcity. Reasons for water scarcity are increasing world populations, global warming and water pollution.

Currently towards 35% of human water use is unsustainable, humans currently use 40-50% of the globally available freshwater. Potable water consumption for nonresidential buildings is heavily dependent on use. Hotels have a proportionally higher requirement that can be accounted for, primarily, through washing and catering needs.

The Red Sea region is one of the potential touristic zones facing water shortage in Egypt, although its touristic development strategies are primarily based on water availability. The sustainable use of water implies resource conservation, environmental friendliness, technological appropriateness, economic viability, and social acceptability of development issues.

Water should be conserved during the whole project life cycle including design, construction and operation phases. Main approaches for water conservation include efficient use of potable water, reuse of wastewater and innovative use of non-potable water alternatives in all functional sectors of a resort.

Many important decisions regarding a water-efficient building can be made during the operation phase of a resort. Such water-efficient practices should be selected based on design and construction requirements, adaptation with climatic conditions and achievement of water-saving, durability and suitable initial costs.

The research aims to preparing a classification for all water efficient techniques that can be used in resorts along Red Sea coasts including potable water techniques and non-potable water applications. Another aim is to define all decisions that help architects to select the suitable water efficient techniques used in Red Sea resorts.

The research discusses water efficient techniques used during operation phase. Then an analytical review is performed for the progress of water efficient scenarios in case studies. Finally, a classification is prepared for water efficient techniques used in resorts along Red Sea coasts.

Abstract

The increasing awareness of the accelerating rate of depletion of water resources is resulting in the high level of demand for water-efficient buildings. Currently towards 35% of human water use is unsustainable, drawing on diminishing groundwater and reducing the flows of major rivers: this percentage is likely to increase if climate change worsens especially "Global Warming", populations increase, groundwater becomes progressively depleted and supplies become polluted and unsanitary .

The Red Sea region is one of the potential touristic zones facing water shortage in Egypt, although its touristic and economic development strategies are primarily based on water availability. The Red Sea region has no surface water sources, low rainfall seasons on highlands and high-saline coastal ground water aquifers. The sustainable use of water implies resource conservation, environmental friendliness, technological appropriateness, economic viability, and social acceptability of development issues. Innovation includes the adaptation of traditional know-how to the current day challenges, the adaptation of the externally available technologies to the prevailing physical and social conditions .

The design, construction and operation of buildings have a tremendous impact on our environment and our natural resources. Green operation practices reduce resource use and pollution while increasing the value derived from each resource used. The building operation practices are large consumers of water. Many important decisions regarding a water-efficient building can be made during the operation phase. Some of these important decisions are using potable water efficient techniques, depending on waste water treatment methods and utilizing non-potable water applications. Water-efficient practices should be selected based on design and construction requirements, adaptation with climatic conditions and achievement of water-saving, durability and suitable initial costs .

In this thesis, studying different water-efficient techniques which can be used in the Egyptian Red Sea region. First, categorizing all discused techniques based on type of water used (potable or non-potable water). Then, analysis of water consumption in all indoor functional sectors of the selected resort case studies along the Red Sea coast. Finally, concluding a rating categorization for the different water-efficient techniques which can be used during a resort operation. It also defines the related decisions made by architects to choose the suitable water-efficient techniques during design process or after the construction of a resort in the Red Sea region.

Key words

- Water
- Water shortage
- Sustainability
- Water conservation
- Water efficiency
- Egypt
- Red Sea
- Tourism
- Eco-resort
- Efficient technique
- Non-potable water
- Graywater
- Resort sectors
- Consumption
- Savings

Research problem

Water is becoming scarce not only in arid and drought prone areas, but also in regions where rainfall is relatively abundant. Scarcity is now viewed under the perspective of the quantities available for economic and social uses, as well as in relation to water requirements for natural and man-made ecosystems. Developments have been undertaken without sufficient care being given to conserving the natural resource, avoiding wastes and misuse, and preserving the quality of the resource.

The Egyptian Red Sea region includes the western Red Sea coast and south Sinai coasts on the two gulfs of Suez and Aqaba. In 2020, water total capacity will reach 595,000 m^3/day in this region including Nile water, groundwater and desalinated sea water. While the total water demand is estimated to reach 1,600,000 m^3/day. This means an estimated water shortage of 1,005,000 m^3/day in the Red Sea region by 2020.

Tourism development is the second largest water-consuming sector in the Red Sea governorate after agriculture, unlike south Sinai governorate where tourism development is the largest among other sectors. Currently, most resorts on the coast meet their fresh water requirements through the desalination of sea water or brackish beach well groundwater which require high initial costs and energy consumption.

Tourism development is considered to be one of the main development strategies for the Red Sea zone. Although there is a great demand for fresh water in the Red Sea area to cope with planned development, the Egyptian Red Sea region is considered one of the most regions in Egypt facing an extreme water shortage.

The research question focuses on the possibility of improving the existing resorts, future extensions and further planned resorts in the Red Sea region to use potable water efficiently as well as benefiting from all non-potable water alternatives available in order to face the extreme water shortage in the Red Sea region.

Research objectives

Research objectives can be explained in the following points:

Objective 1:

Preparing a classification for all water efficient techniques that can be used in resorts along Red Sea coasts including potable water techniques and non-potable water applications.

Objective 2:

Defining all decisions that help architects to select the suitable sites, as well as the suitable water efficient techniques used in Red Sea resorts.

Methodology

The following methodologies are used throughout the thesis:

- Analytical study.
- Field study.
- Comparative analysis.

Research Structure

The thesis mainly consists of:

Chapter 1: Water crisis
Chapter 2: Tourism development affecting water availability in the Red Sea region
Chapter 3: Considerations for water efficiency in resorts during design and construction phases
Chapter 4: Water efficient usage in resorts during operation phase
Chapter 5: Comparative analytical methodology for water consumption during operation phase
Conclusion and Recommendation

Table of Contents

List of figures

List of tables

Chapter one: Water crisis

1.1. Water shortage
1.2. Sustainability
1.3. Water Efficient Architecture

Decades ago, water was viewed as a non-limited natural resource because it was renewed every year in the course of the seasons. Man progressively appropriated this resource and used it with few restrictions. Developments in controlling and diverting surface waters, exploring groundwater, and in using the resources for a variety of purposes have been undertaken without sufficient care being given to conserving the natural resource, avoiding wastes and misuse, and preserving the quality of the resource.

Thus, nowadays, water is becoming scarce not only in arid and drought prone areas, but also in regions where rainfall is relatively abundant. Scarcity is now viewed under the perspective of the quantities available for economic and social uses, as well as in relation to water requirements for natural and man-made ecosystems. [1]

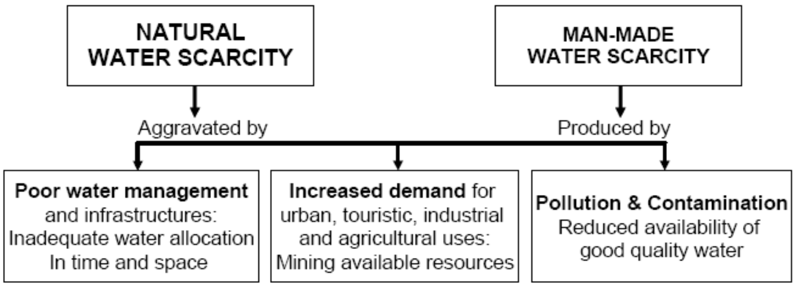


Figure 1 Natural and man-made water scarcity **(Pereira, Cordery, & Iacovides, 2009)**

The figure shows natural and man-made water scarcity can be increased as a result of poor water management and infrastructures, increased demand or water pollution and contamination.

1.1. Water shortage

In the decade 1951-60 human water withdrawals were four times greater than the previous decade. This rapid increase resulted from scientific and technological developments impacting through the economy - especially the increase in irrigated land, growth in industrial and power sectors, and intensive dam construction on all continents. This altered the water cycle of rivers and lakes, affected their water quality and had a significant impact on the global water cycle. [2]

[1] Pereira, L. S., Cordery, I., & Iacovides, I. (2009). *Coping with Water Scarcity : Addressing the Challenges.* Springer Science+ Business Media.

[2] wikipedia. (n.d.). *Water crisis*. Retrieved 2009, from wikipedia: http://en.wikipedia.org/wiki/Water_crisis

The lowest annual potential water availability per capita is for North Africa (710 m^3/capita) where water scarcity is very high.[1] This region has an arid or semi-arid climate and high growth of population. It also had ancient civilizations that had developed over centuries.

In water scarce regions, as is the case for the Middle East and North Africa regions, that share averages 73% of the total water resources (The World Bank 1992). This situation illustrates that not only the potential water availability in these regions is low but that sustaining an increased demand requires innovative approaches to cope with water scarcity.

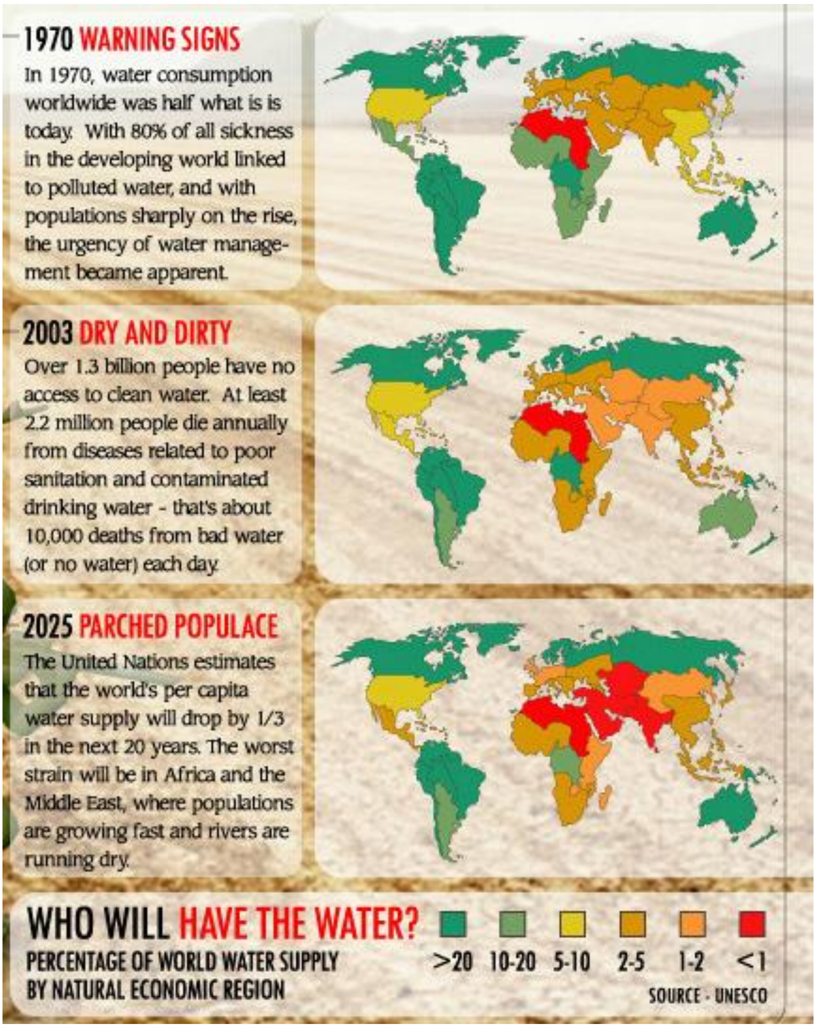


Figure 2 Water withdrawal percentages
(U.N., The Millennium Development Goals Report, 2008)

In Middle East and North African regions near 53% of the per capita annual withdrawals for all uses, including irrigation, are below 1000 m^3/year and 18% are between 1000 and 2000 m^3/year. The importance of water scarcity in these regions is obvious when it is noted that estimates for the average annual growth of the population in these regions are among the World's highest: 2.9% for 1990–2000, 2.3% for 2000–2035 for the Middle East and North Africa. Forecasts for the next decades show that water scarcity or water stress may affect a very large number of countries.

Reasons for water shortage are:

A. Increasing world populations

Water use has grown at more than twice the rate of the population for the past century. Although there is not yet a global water shortage, about 2.8 billion people, representing more than 40 per cent of the world's population, live in river basins with some form of water scarcity .More than 1.2 billion of them live under conditions of physical water scarcity, which occurs when more than 75 per cent of the river flows are withdrawn. Northern Africa and Western Asia are seriously compromised, as some regions within large countries such as China and India . Symptoms include environmental degradation and competition for water. [3]

B. Global Warming

Some scientists say that global warming is the single greatest cause of the fresh water shortage in the world. A rise in average temperature in mountainous regions can alter the precipitation mix between rainfall and snowfall, with more rain and less snow. This change means more flooding and more runoff during the rainy season, but also less water held as snow and ice in the mountains for use in the dry season. These mountain glaciers or "reservoirs in the sky" are all melting.

There are some impacts caused by Global Warming on water resources. These impacts are as shown below: [4]

- Change in amounts, places and patterns of rainfall; leading to increase floods and droughts.
- Some studies show that Nile flow may decrease by 60%.
- Saltiness of coastal aquifers due to the increase in seawater intrusion.

[3] U.N. (2008). *The Millennium Development Goals Report.* New York: United Nations.

[4] webofcreation. (n.d.). *Earth Problems/water*. Retrieved 2009, from webofcreation: http://www.webofcreation.org/Earth%20Problems/water.htm

C. Pollution

Most of the pesticides and fertilizers used in agriculture, sewer overflows, and the oil and grease from roads, eventually run off into the water systems. Other sources of excess nutrients include lawn fertilizers, pet and farm animal waste, decaying plant material, failing septic tanks, and inefficient sewage treatment plants. Industrial plants and municipal wastewater treatment plants can also contribute to the amount of toxic substances entering streams and rivers and ultimately lakes, estuaries, and coastal waters.

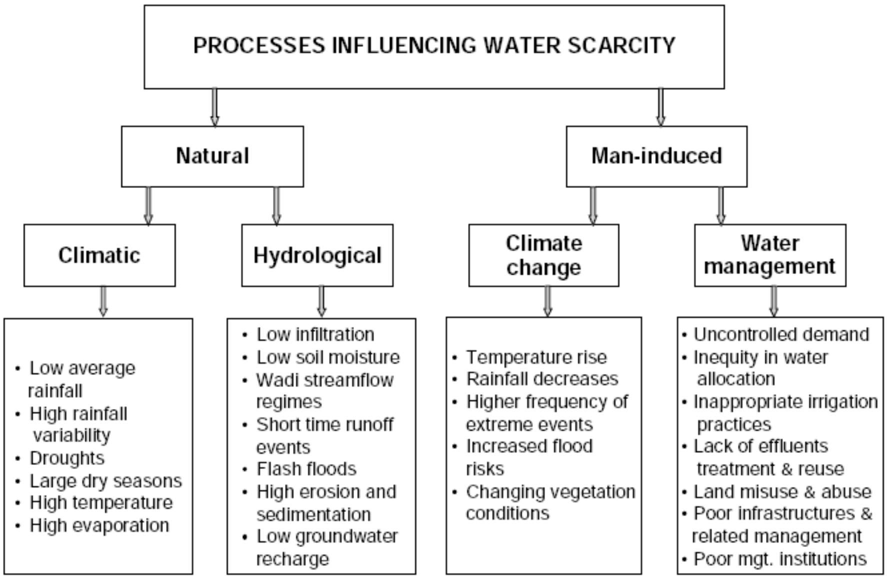


Figure 3 Natural and man-induced processes favouring water scarcity **(Pereira, Cordery, & Iacovides, 2009)**

Figure 3 shows how water scarcity can be aggravated by nature and man; nature can affect climate and hydrology while man is responsible for climate change and water management.

1.1.1. Water wars

Many developing nations possess poor water-supply infrastructure and their industries and cities continue to pour wastes into local waters. Many of these countries have the world's highest population growth rates in the world. The World Bank and the WHO estimate that between 1.1 and 1.4 billion people in developing countries have inadequate access to water. [5]

[5] Maczulak, A. E. (2010). Green technology. In A. E. Maczulak, *Conservation: Protecting Our Plant Resources.* New York: Facts On File, Inc.

War and threat of genocide contributes by driving millions of people to areas where water and food are in short supply.

Water status for some world countries (2010)		
Severe water stress	More than 90% of land in water stress	Israel - Trinidad and Tobago - Syria - Nepal - KuwaitAzerbaijan - Belgium - Tajikistan - Kyrgystan - Turkmenistan - Macedonia - Tunisia
High water stress	More than 75% of land in water stress	Saudi Arabia - Egypt - Iran - Uzbekistan - Iraq - Armenia - Libya - Jordan - Lebanon - Morocco - India - Pakistan
Moderate-To-High water stress	From 35% to 75% of land in water stress	United Arab Emirates - Spain - Algeria - South Africa - Turkey - Kazakhstan - Greece - Portugal - South Korea - Oman - Bulgaria - China - Mexico - Chile - Niger - Sri Lanka - the Netherlands
Moderate water stress	From 15% to 34% of land in water stress	United States - Sudan - Somalia - Italy - Ethiopia - Cuba - Peru Argentina - Bangladesh - United Kingdom - Albania - France - Namibia - Nigeria - Ukraine - Zimbabwe
Low-To-Moderate water stress	From 5% to 14% of land in water stress	Botswana - Bolivia - Mozambique - Philippines - Japan - Mangolia - Australia - Denmark - Mauritania - Moldova - Senegal
Low water stress	Less than 5% of land in some water stress	Dominica - Russia - Vietnam - North Korea - Mali - Venzuela - Chad - Finland - Romania - Madagascar - Malaysia - Indonesia - Ecuador - Kenya - Germany - Colombia - Canada - Thailand - Sweden - Lithuania - Norway - Nicaragua - Brazil - Estonia
No water stress at present		Angola - Austria - Belarus - Benin - Bosnia and Herzegovina - Burkina Faso - Burma - Burundi - Cambodia - Cameroon - Costa Rica - Croatia - Czech Republic - Democratic Republic of Congo - El Salvador - Ghana - Guatemala - Guinea - Haiti - Honduras - Hungary - Iceland - Ireland - Laos - Latvia - Liberia - New Zealand - Panama - Papua New Guinea - Paraguay - Poland - Rwanda - Sierra Leone - Slovakia - Slovenia - Switzerland - Tanzania - Togo - Uganda - Uruguay - Zambia

Note: Countries are listed within each category from most stressed to least stressed except for the "No water stress at present "category in which countries are in alphabetical order .

Table 1 Water status for some world countries **(Maczulak, 2010)**

The global Water Wars have long been predicted and there are a number of flash points for such conflicts around the world. Countries in the Middle East are already experiencing conflicts and genocide. Some examples are:

- The struggles between Nile riparian countries; Tensions have emerged on sharing resources as the needs of the riparian countries are increasing, especially between Egypt, Ethiopia and Sudan which are thought by many political experts to be under the greatest threat of a war over water.
- The struggle between Turkey, Syria and Iraq over the waters of the Tigris and Euphrates rivers.
- The water crisis of River Jordan between Jordan, Palestine and Israel suffering from cultural strife made worse by water shortage.

1.1.2. Current water usage percentages

Currently towards 35% of human water use is unsustainable, drawing on diminishing aquifers and reducing the flows of major rivers: this percentage is likely to increase if climate change worsens, populations increase, aquifers become progressively depleted and supplies become polluted and unsanitary. From 1961 to 2001 water demand doubled - agricultural use increased by 75%, industrial use by more than 200%, and domestic use more than 400%. Humans currently use 40-50% of the globally available freshwater in the approximate proportion of 70% for agriculture, 20% for industry, and 10% for domestic purposes and the total volume is progressively increasing. [4]

Current percentages for worldwide fresh water usage are as followed:

- **70% of all the fresh water is used for agriculture** - Countries are importing food as a way to import water. Producing one ton of grain requires 1000 tons of water, but producing one ton of beef or cotton requires 15,000 tons of water. [4]
- **20% of Fresh Water is used by Industry** - As water becomes scarce, demand for water in cities and by industry is satisfied by taking water from a country's agriculture. [4]
- **10% of fresh water is used for domestic use** - Domestic use accounts for three-fourths of the urban water demand. Each day in the U.S., more than 4.8 billion gallons of drinking water is flushed down toilets. [4]

1.1.3. Water Requirements

The main consumers of drinking water are private households, small commercial operations and industry. Drinking water consumption for nonresidential buildings is heavily dependent on use. Hotels, hospitals and senior care homes have a proportionally higher requirement that can be accounted for, primarily, through washing and catering needs. [6]

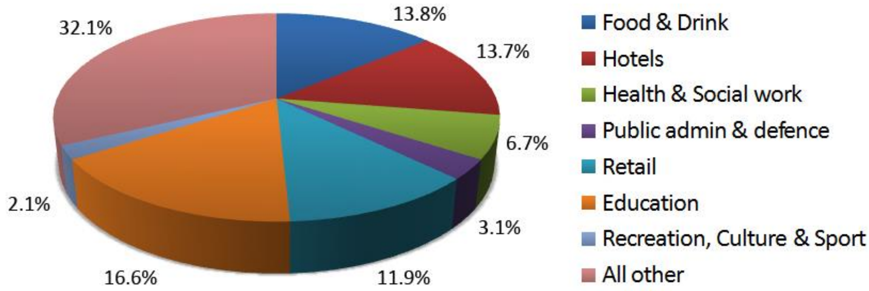


Figure 4 An example for water usage distribution: main commercial/industrial sectors in England and Wales **(Government, 2010)**

Figure 4 shows that hotels are located in average zone of water use rates exceeding those of health, social, retail, recreation, culture, sport and others.

The sustainable use of water implies resource conservation, environmental friendliness, technological appropriateness, economic viability, and social acceptability of development issues. The perception that water is increasingly scarce gives to water management a great relevance.

1.2. Sustainability

The design, construction and maintenance of buildings have a tremendous impact on our environment and our natural resources. All around the world, a huge amount of buildings are being constructed with many more to be done.

The challenge will be to build them smart with a minimal usage of non-renewable energy, minimal production of pollution, and minimal costs. Indeed, buildings consume many of the natural resources and are responsible for many problems.

The following is a discussion of some approaches related to Architecture and Economy.

[6] Bauer, P. D., Schwarz, D. M., & Mösle, P. (2010). *Green Building - Guidebook for Sustainable Architecture.* Berlin: Springer-Verlag.

1.2.1. Sustainable Economics

Both big business and the conservation lobby should not take the shortsighted view that provide profitably for the needs of mankind and manage the earth's resources are not mutually inclusive. On the contrary, the idea of 'sustainable development' ensures sustaining social and environmental goals through prudent human and natural resource management, while providing for short- and long-term horizons. Sustainability will provide fair treatment of future generations.

1.2.1.1. Blueprint for a green economy

The real price of energy and water, waste management and pollution coupled with the cost to those caught in urban poverty, implies a socio-economic problem. Fundamental to an understanding of sustainable development is the fact that the economy is not separate from the environment in which we live. There is an interdependence because the way we manage the economy impacts on the environment, and because environmental quality impacts on the performance of the economy. [7]

In environmental economics, two general classes of environmental problem:

- **Pollution:** It is the unnatural concentration of materials in the environment, and is essentially the residual of human activity, adversely affects the next user of some environmental resource, and even the resource itself, and therefore man's well-being.

- **Resource destruction:** It is the removal or dispersion of natural concentrations of materials that impairs some ecological process or depletes some environmental resource otherwise capable of yielding benefits in perpetuity. [7]

Resource destruction and pollution problems both result from the reallocation of resources through economic activity, of which there are three, namely, land (all natural systems in the biosphere), labor and capital. Economics is the science of allocating scarce resources among competing ends. [7]

1.2.1.2. Economic principles

Together with changes of habit in the more responsible consumption of resources, appropriate technology is at the core of the resource conservation solutions. But, the most effective mechanism for checking the culture of rampant consumerism lies in the application of economic principles.

[7] Thomas, D. (2002). *Architecture and the Urban Environment: A Vision for the New Age.* Oxford: Architectural Press.

A. The user-pays principle

It could be constructive to conduct a research program aimed at educating the consumer into the social costs of their use of resources, such as water and electricity. A captive user would, for example, be a visitor to a nature reserve or resort. They could have the option of being supplied through metered energy and water resource-saving devices that have been installed in the units.

User-pays measures have the potential to significantly influence the pattern of use of key resources through economic inducement. To further correct consumer attitudes to water conservation, energy conservation, recycling and pollution control the project should be extended through a follow-up test of the 'take-home' effect of these measures. [7]

B. The payback principle

Taking into account that planning and implementation of major upgrading projects for metropolitan utilities, such as for water and electricity, takes at least a decade, a 'payback' approach to planning would assist in the decisions regarding policy. A longer-term vision should become mandatory for all projects in urban situations, where demand for services is outstripping existing infrastructure and requiring further large capital investment. [7]

1.2.2. Sustainable Architecture

The study of the global and local environment and the recognition of its degradation led to studies on sustainability. Sustainability was defined in the Brundtland Report of the World Commission on the Environment and Development in 1987 and this definition is:"Sustainable development is the development that meets the needs of the present without compromising the ability of future generations to meet their own needs". [8]

For architects, structural engineers and others engaged in construction, building and urban life, indicators are to be calculated that reflect as well as possible the impact on sustainability. Sustainability requires the conservation of the world's resources of energy, fossil fuels, minerals, forests, land; and safeguarding the quality of the environment (clean air, soil and water).

The main goal of sustainable architectural design is to identify and integrate solutions into the planning process that minimize these impacts and insure a more sustainable environment for future generations. This design should achieve sustainability for environment, economy and society through respecting all basics shown in the figure below.

[8] Sebestyen, G., & Pollington, C. (2003). New Architecture and Technology. Oxford: Architectural Press.

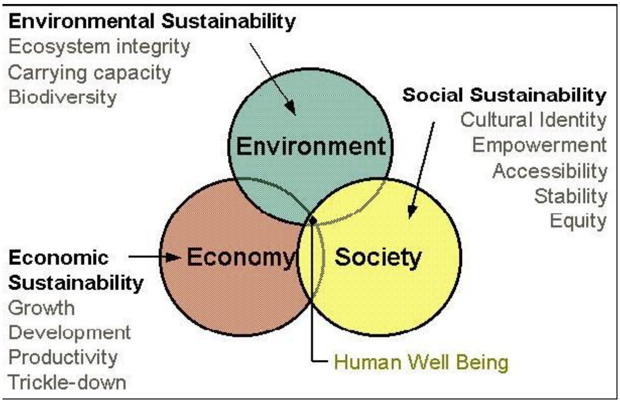


Figure 5 Three Dimensions of sustainable development **(El Feky, 2006)**

The construction and occupation of any building affects the local, national, and global environments through a series of interconnected human activities and natural processes. This is particularly evident in the accommodation sector in the Red Sea Region. For instance:

- The construction, equipment and personnel that are required for the building process disturb or even destroy the ecology of the site as well as possibly the marine environment.

- The procurement and manufacturing of building materials and equipment, for these resorts and hotels has an impact on the global environment (pollution, carbon emissions, etc).

- Once built and operational, the facility creates an on-going and long-lasting impact on the environment.

  – The energy and water used by its inhabitants produce toxic gases and sewage.
  – The process of extracting, refining, and transporting all the resources used in building operation and maintenance also has numerous effects on the environment.

1.2.2.1. Sustainable Architecture principles

Jong-Jin Kim, at University of Michigan's College of Architecture and Urban Planning proposes three principles of sustainability in architecture. These principles generate an understanding of the various environmental impacts, (local and global) of architectural consumption. [9] They include:

[9] (USAID), T. U. (MARCH 2008). *LIFE Red Sea Project - Enhancing Sustainable Tourism in the Southern Red Sea Region of Egypt.* Chemonics International.

A. Economy of Resources

The principle addresses the reduction, reuse and recycling of the natural resources that are the input to a building. [9]

- Emphasis on the reduction in the use of nonrenewable resources in the construction and operation of buildings.

- After the eco-resorts' useful life, it should turn into components for other buildings.

- The architect needs to consider two streams of resource flow:

  – *Upstream* resources flow into the building as input to the building ecosystem.
  – *Downstream* resources flow out of the building as output from the building ecosystem. Eventually any resources entered into a building ecosystem will eventually come out from it.

Economy of resources involves:

o Energy Conservation

– An eco-resort requires a constant flow of energy input during operations and energy consumed in the process of catering to the guest such as cooling fans, lighting, food preparation and equipment operation cannot be recovered.
– The use of renewable energy technologies reduces emissions of polluting gases

o Water Conservation

– The tourist accommodation requires large quantities of water for the drinking, cooking, washing and cleaning, flushing toilets, irrigating plants, etc.
– Water requires desalination, treatments and elimination of the salt by-product which consume energy.
– The water that exits the eco-resort must also be treated and disposed.

o Material Conservation

– Many different building materials are brought onto the sites during the construction of the eco-resort.

- The waste generated by the construction and installation process is significant.
- After construction, a low-level flow of materials continues in for maintenance, replacement, and renovation activities.
- Consumer goods flow into the building to support the tourism activities. All of these materials are eventually output, either to be recycled or dumped in a landfill.

B. Life Cycle Design

The principle provides a methodology for analyzing the entire building process and its impact on the environment. [9]

- The conventional model of a resort life cycle is a linear process consisting of four major phases: design; construction; operation and maintenance; and demolition.

- This model does not address environmental issues (related to the procurement and manufacturing of building materials) or waste management (reuse and recycling of architectural resources).

- Life cycle design (LCD) or "cradle-to-grave" approach recognizes environmental impacts of the entire life cycle of architectural resources, from procurement to return to nature. LCD is based on the notion that a material continually moves from one form of useful life to another, with no end to its usefulness.

The life cycle of a building can be categorized into three connected phases:

o Pre-Building Phase

- Including site selection, building design, and building material processes, up to but not including installation

.

- The environmental consequences of the structure's design, orientation, impact on the landscape, and materials used are assessed in terms of sustainable design.

- Building materials environmental impacts include:

  - Harvesting uncertified trees result in deforestation.
  - Mining mineral resources (iron for steel; bauxite for aluminum; sand, gravel, and limestone for concrete) disturbs the natural environment.
  - The transport of these materials generates pollution, depending on their weight and distance from the site.

– The manufacturing of building materials also requires energy and creates pollution: especially steel, aluminum and concrete products.

- **Building Phase**

  - Sustainable architecture examines the construction and operation processes for ways to reduce the environmental impact of resource consumption. Considering long-term health effects of the resort environment on the guests and staff.

- **Post-Building Phase**

  - After the useful life of the eco-resort its building materials become resources for other buildings or waste to be returned to nature. Sustainable architecture focuses on reducing construction waste by recycling.

C. Humane Design

The principle focuses on the interactions between the eco-resort guest and staff and the environment. [9]

- Humane design is concerned with the livability of all constituents of the global ecosystem including topography, plants and wildlife. Focus on enhancing the coexistence between buildings and the greater environment, and between buildings and the guest.

- Sustainable architecture provides built environments that sustain the guests safety, health, physiological comfort, psychological well-being, and as well as ensures staff comfort and productivity.

1.2.3. Green Architecture

Green construction protects healthy sites, conserves regional habitat, stimulates a stable and diverse local economy and improves local quality of life and human health. The U.S. Green Building Council has defined green buildings as "structures that are designed, renovated, constructed, operated and environmentally demolished in an environmentally and energy efficient manner with least impact upon our global and internal environment". [10]

[10] El Feky, U. M. (2006). *Toward Applicable Green Architecture : An Approach to Colonize the Desert in Egypt.* Eindhoven: Universiteitsdrukkerij, Technische Universiteit Eindhoven.

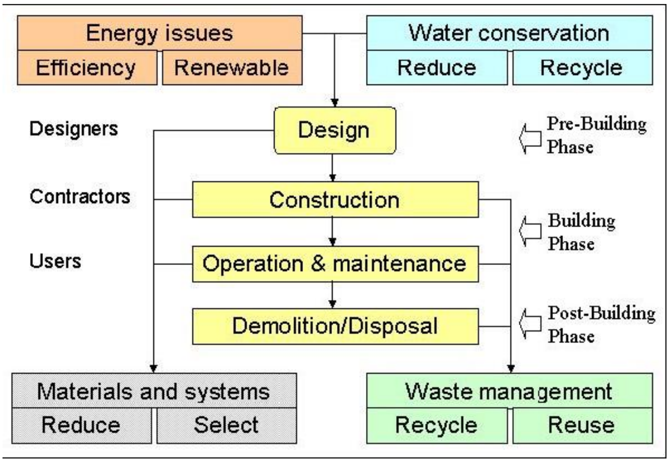


Figure 6 The processes of green architecture **(El Feky, 2006)**

Figure 6 shows the role of designers, contractors and users in achieving the efficiency of energy, water, materials and waste in any project life cycle starting from design and ending with demolition.

Green Building is defined as "building methods and materials that conserve energy, water and resources, use low impact materials, maximize longevity and durability, minimize waste, recycles other buildings and makes buildings and homes healthier". The main Green Architecture Principles [Set 3, 2002] are as followed: [10]

- Smaller is better. Optimize use of interior space through careful design so that the overall building size, resource use in constructing and operating process are kept at a minimum.

- Design an energy-efficient building. Use high levels of insulation, high-performance windows, and tight construction.
- Design buildings to use renewable energy. Passive solar heating, day lighting, and natural cooling can be incorporated cost-effectively into most buildings. Also consider solar water heating and photovoltaic.

- Optimize material use. Minimize waste by designing for standard ceiling heights and building dimensions. Simplify building geometry.

- Design for water-efficient, low-maintenance landscaping. Conventional lawns have a high impact because of water use, pesticide use, and pollution generated by lawn mowers.

- Landscape with drought-resistant native plants and perennial ground covers.
- Avoid potential health hazards: radon, mould, and pesticides.

- Make it easy for occupants to recycle waste. Make provisions for storage and processing of recyclables.
- Look into the feasibility of using grey water. Water from sinks, showers, and washing machines can be recycled for irrigation in some areas.
- Design for durability. To spread the environmental impacts of building over as long a period as possible, the structure must be durable. Durable aesthetics "timeless architecture" are also important.
- Design for future reuse and adaptability. Make the structure adaptable to other uses, and choose materials and components that can be reused or recycled.

1.2.3.1. Relation between Green and Sustainable Building

Sustainable building - Sustainable is the threshold where, over their lifetime, a building's resource use and waste production are in balance with the earth's natural services. A sustainable building must also be economically viable and socially equitable, achieving the "three E's" of sustainability - environment, economy and equity. [10]

Green Building - Green building is the path to get from conventional to sustainable building.

1.2.3.2. Rating Systems and Design Guides

More efforts have been done to benchmark the building environment from the green architecture point of view. Thus, a large number of systems have been developed to analyze building sites and buildings from the green architecture point of view. The rating systems are organized in the form of a checklist, which gives credit points to existing buildings. Commercial construction certification schemes like LEED, BREEAM are just a few examples of reinforcement of these processes.

1.3. Water Efficient Architecture

The following are two water-saving approaches that can reduce water consumption in buildings.

1.3.1. Water conservation

1.3.1.1. Definition

Water conservation is defined as: [11]

- Any beneficial reduction in water loss, use or waste.
- Improved water management practices that reduce or enhance the beneficial use of water. A water conservation measure is an action, behavioral change, device, technology, or improved design or process implemented to reduce water loss, waste, or use.

1.3.1.2. Main goals of water conservation

The Main goals of water conservation are as followed:

- **Sustainability**
    - To ensure availability for future generations, the withdrawal of fresh water from an ecosystem should not exceed its natural replacement rate.
- **Energy conservation**
    - Water pumping, delivery and wastewater treatment facilities consume a significant amount of energy. In some regions of the world over 15% of total electricity consumption is devoted to water management.
- **Habitat conservation**
    - Minimizing human water use helps to preserve fresh water habitats for local wildlife and migrating waterfowl, as well as reducing the need to build new dams and other water diversion infrastructure.

[11] wikipedia. (n.d.). *Water conservation*. Retrieved 2010, from wikipedia: http://en.wikipedia.org/wiki/Water_conservation

1.3.2. Water efficiency

1.3.2.1. Definition

Water efficiency is defined as: [12]

- The accomplishment of a function, task, process, or result with the minimal amount of water feasible.
- An indicator of the relationship between the amount of water required for a particular purpose and the amount of water used or delivered.

1.3.2.2. Relation between water conservation and efficiency

Water efficiency differs from water conservation in that it focuses on reducing waste, not restricting use. It also emphasizes the influence consumers can have by making behavioral changes and using more water efficient products. These things fall under the definition of water efficiency, as their purpose is to obtain the desired level of service with the least necessary water. Accordingly, water efficiency falls under the general umbrella of water conservation.

1.3.2.3. Advantages of water efficient buildings

The building industry is the largest consumer of raw materials in the world today after food production. A major guiding principle for the future should be a drastic reduction in the use of raw materials. This is best applied to the less common nonrenewable resources, but is also necessary for others. [13]

Another important aspect to address is to reduce the loss of resources during production, the construction process and throughout the life of the completed building. The re-use of materials following demolition should also be taken into account. Recycling processes should be developed so that materials can be taken care of at their original level of quality, rather than down-cycled. [13]

Although there are many opportunities for water conservation and benign disposal, the wide availability of mains water, sewerage and storm water drainage connections means that water issues are rarely considered in building projects. However, there are benefits to such considerations at the earliest stage in design and refurbishment. The designer is presented with complex choices; motivation, impact, management and cost will all influence the most sustainable solution.

[12] wikipedia. (n.d.). *Water efficiency*. Retrieved 2010, from wikipedia: http://en.wikipedia.org/wiki/Water_efficiency

[13] Berge, B. (2009). *The Ecology of Building Materials - Second edition.* Oxford: Elsevier Ltd. - Architectural Press.

Good building design responds to the local environment. Sustainable water management is particularly sensitive to context and resistant to standard 'bolt-on' solutions. Solutions such as dry toilets may not only be a sustainable option, but the only practical one for the most constrained sites: developments in remote locations and buildings on rock or heavy clay. [14]

Chapter conclusions

From this chapter, conclusions can be summarized as followed:

1. Water is becoming scarce not only in arid and drought prone areas, but also in regions where rainfall is relatively abundant. Scarcity is now viewed under the perspective of the quantities available for economy, social uses and ecosystems.

2. Developments have been undertaken without sufficient care being given to conserving the natural resource, avoiding wastes and misuse, and preserving the quality of the resource.

3. Sustainability requires the conservation of the world's resources such as sources of energy, water, fossil fuels, minerals, forests, land; and safeguarding the quality of the environment.

4. The increasing awareness of the accelerating rate of depletion of water resources is resulting in the high level of demand for water-efficient buildings.

5. Water conservation can be defined as any beneficial reduction in water loss, use or waste by implementation of water conservation or water efficiency measures.

[14] Halliday, S. (2008). *Sustainable Construction.* Oxford: Elsevier.

Chapter two: Tourism development affecting water availability in the Red Sea region

2.1. Red Sea fresh-water resources
2.2. Development statistics for existing and expected resorts in the Red Sea region

2.1. Red Sea fresh-water resources

2.1.1. The hydrological situation in Egypt

With a population growth of about 2.4% (approx. 1.7 mill. inhabitants per year), the two main urgent public utility problems of Egypt are potable water and sewage. Water resources in Egypt are becoming scarce. Surface-water resources originating from the Nile are now fully exploited, while groundwater sources are being brought into full production. Egypt is facing increasing water needs, demanded by a rapidly growing population, increased urbanization, higher standards of living and an agricultural policy, which emphasizes expanded production in order to feed the growing population. [10]

Before discussing the water situation, some general definitions and facts should be noticed:

2.1.1.1. General definitions

2.1.1.1.1. Aridity

Aridity is a natural permanent imbalance in the water availability consisting in low average annual precipitation, with high spatial and temporal variability, resulting in overall low moisture and low carrying capacity of the ecosystems.[1]

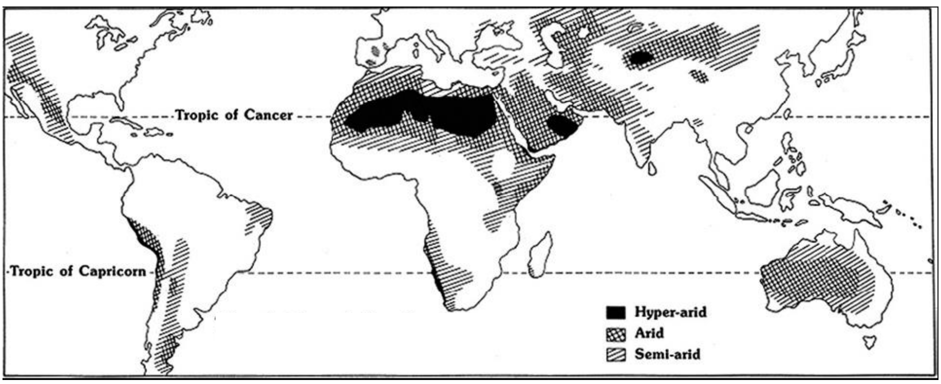


Figure 7 The world arid and semi-arid regions **(Pereira, Cordery, & Iacovides, 2009)**

Under aridity, extreme variations of temperatures occur, and the hydrologic regimes are characterized by large variations in discharges, flash flood and long periods with very low or zero flows. The figure above shows that Egypt is located in a hyper-arid to arid zone.

2.1.1.1.2. Water shortage

Water shortage is also a man-induced, sometimes temporary water imbalance including groundwater and surface waters over-exploitation resulting from attempts to use more than the natural supply, or from degraded water quality, which is often associated with disturbed land use and altered carrying capacity of the ecosystems.

2.1.1.1.3. Groundwater

Most of the hydrogeologic features of arid regions are related to the quantity and quality of available ground water. In dry regions, groundwater is a very important source of freshwater for domestic, agricultural, and industrial use, and it may be the only source of water supply over large parts of the year.

Due to the great quest for more water in these regions, aquifers are in many cases overexploited, and suffer much degradation, such as lowering of the water level, salinization and intrusion of marine water, and mineral and organic pollution.[1] This is more pronounced in areas of water scarcity where water from aquifers of varying quality is imported and blended with surface waters to maintain existing land uses and to meet other demands.

The mining of these aquifers also entails increasingly heavy constraints, even if the estimated storage is huge compared with the annual consumption. Their development and use must be based on sound hydrologic studies since overexploitation will inevitably result in their depletion and extinction.

2.1.1.1.4. Infiltration and Soil Water

Beneath the groundwater table an area of higher density lies where all the air has been squeezed out to make room for water. This location, called the zone of saturation, holds water undisturbed for longer periods than the water table. Therefore, water moves through three layers in the earth: [5]

1. The upper unsaturated zone, where soils hold varying amounts of moisture (also called the soil zone).
2. The water table, where water exchanges from the saturated layer below to the unsaturated layer above.
3. The zone of saturation.

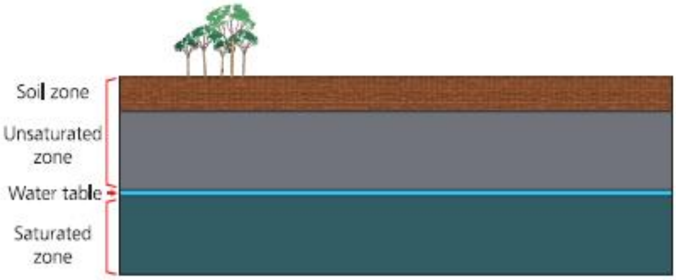


Figure 8 Groundwater table **(Maczulak, 2010)**

2.1.1.2. Water resources in Egypt

The Egyptian territory comprises the following river basins : [15]

- The Northern Interior Basin, covering 520 881 km^2 or 52 percent of the total area of the country in the east and southeast of the country. A sub-basin of the Northern Interior Basin is the Qattara Depression.
- The Nile Basin, covering 326 751 km^2 (33 percent) in the central part of the country in the form of a broad north-south strip.
- The Mediterranean Coast Basin, covering 65 568 km^2 (6 percent).
- The Northeast Coast Basin, a narrow strip of 88 250 km^2 along the coast of the Red Sea (8 percent).

The River Nile is the main source of water for Egypt, with an annual allocated flow of 55.5 km^3/yr under the Nile Waters Agreement of 1959. Internal renewable surface water resources are estimated at 0.5 km^3/yr. This brings total actual renewable surface water resources to 56 km^3/year. [15]

2.1.1.2.1. Rainfall zones

Egypt can be divided into six climatic districts: [16]

- Mediterranean District: the rainiest in Egypt (100-190 mm/year).
- Nile Delta District: The rainfall decreases sharply to (20-50 mm/year).
- Sinai Highlands District: The rainfall reaches (100-190 mm/year).
- Middle Egypt District: The rainfall is very little (< 10 mm/year).
- Upper Egypt District: The rainfall is rare.
- Red Sea District: The region of Red Sea highlands is rainier.

[15] Aquastat. (2005). *Irrigation in Africa in figures.*

[16] Abou Rayan, P. M., & Djebedjian, D. B. (2004). *Egypt's Water Demand, Supply and Management Policies.* Mansoura.

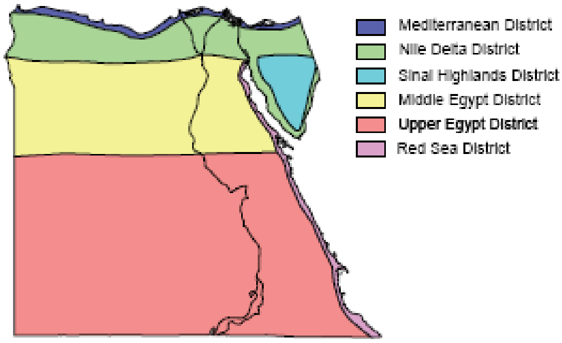


Figure 9 Climatic districts in Egypt **(Abou Rayan & Djebedjian, 2004)**

2.1.1.2.2. Aquifer Systems in Egypt

The hydro-geological framework of Egypt comprises six aquifer systems: [16]

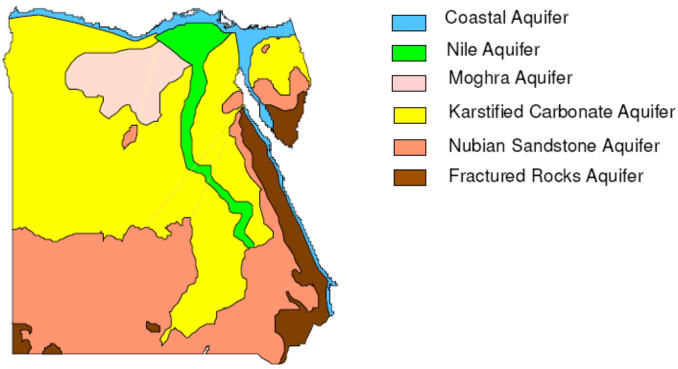


Figure 10 The aquifer systems of Egypt **(Abou Rayan & Djebedjian, 2004)**

- The Nile Aquifer System which occupies the Nile flood plain region (including Cairo) and the desert fringes.
- The Nubian Sandstone Aquifer System which mainly occupies the Western Desert.
- The Moghra Aquifer System occupying the western edge of the Delta.
- The Coastal Aquifer Systems occupying the northern and western coasts.
- The Karstified Carbonate Aquifer System which outcrops in the northern part of the Western Desert and along the Nile system.
- The Fissured and Weathered Hard Rock Aquifer System which outcrops in the Eastern Desert and Sinai.

Table 2 shows that internal renewable groundwater resources are estimated at 2.3 km^3/yr. The overlap between surface water and groundwater being considered negligible, the total actual renewable water resources of the country are thus 58.3 km^3/yr. The Nubian Sandstone aquifer is considered an important groundwater source, but this is fossil groundwater. [15]

Water Input	million m³/yr
Renewable surface water resources	56 000
Renewable groundwater resources	2 300
Reuse of agricultural drainage water (return flow to rivers)*	4 840
Reuse of groundwater (seepage from agriculture)*	6 127
Reused treated wastewater	2 971
Desalinated water	100
Use of fossil groundwater (non-renewable water)	825
Total	**73 163**

Table 2 Water availability in Egypt (2000) **(Aquastat, 2005)**

All drainage water in Upper Egypt, south of Cairo, flows back into the Nile and the irrigation canals; this amount is estimated at 4.84 km^3/yr. Treated domestic wastewater was estimated at 2.97 km^3/yr. There are desalination plants on the coasts of the Red Sea and the Mediterranean to provide water for seaside resorts and hotels; total production was estimated at 100 million m^3. [15]

Estimates of the potential of non-renewable groundwater in the eastern and western deserts, mainly from the Nubian Sandstone aquifer, vary from 3.8 km^3/yr to 0.6 km^3/yr; the latter estimate is defined as an indicator of exploitability over a period of time, where the time is not given. [15]

2.1.1.3. Water use

Total water withdrawal in Egypt during 2000 was estimated at 73.3 km^3. This included 60.7 km^3 for agriculture (86 percent), 4.5 km^3 for domestic use (8 percent) and 7.8 km^3 for industry (6 percent). Apart from that, 0.3 km^3 were used for navigation and hydropower. [15]

Governorate	Tourism Sector	Agriculture Sector	Population Sector	Industry Sector	Total Water Demand
Red Sea	130551	1020000	71000	113600	1335151
South Sinai	93272	34000	14000	22400	163672
North Sinai	-	6992100	57000	91200	7140300
Matroh	-	10676000	86000	137600	10899600
Daily Total	223823	18722100	228000	364800	19538723
Annual Total	81695395	6833566500	83220000	133152000	7131633895

Table 3 Water Requirement for Different Sectors in 2017 **(INECO, March 2009)**

Table 3 shows that water demand for tourism sector in Red Sea is the second highest after agriculture sector. Unlike South Sinai in which the water demand for tourism sector is the highest.

2.1.1.4. Water shortage in Egypt

Egypt, when examined as a single geographic entity does not appear to face water shortage problems. Similarly, the Governorates that are located near the River Nile do not experience water deficit. However, some areas have been identified as having a crucial situation regarding water supply as shown in the figure below. These areas concern Sinai, the Red Sea coast and Northern coast, where economic development is primarily based on water availability. [17]

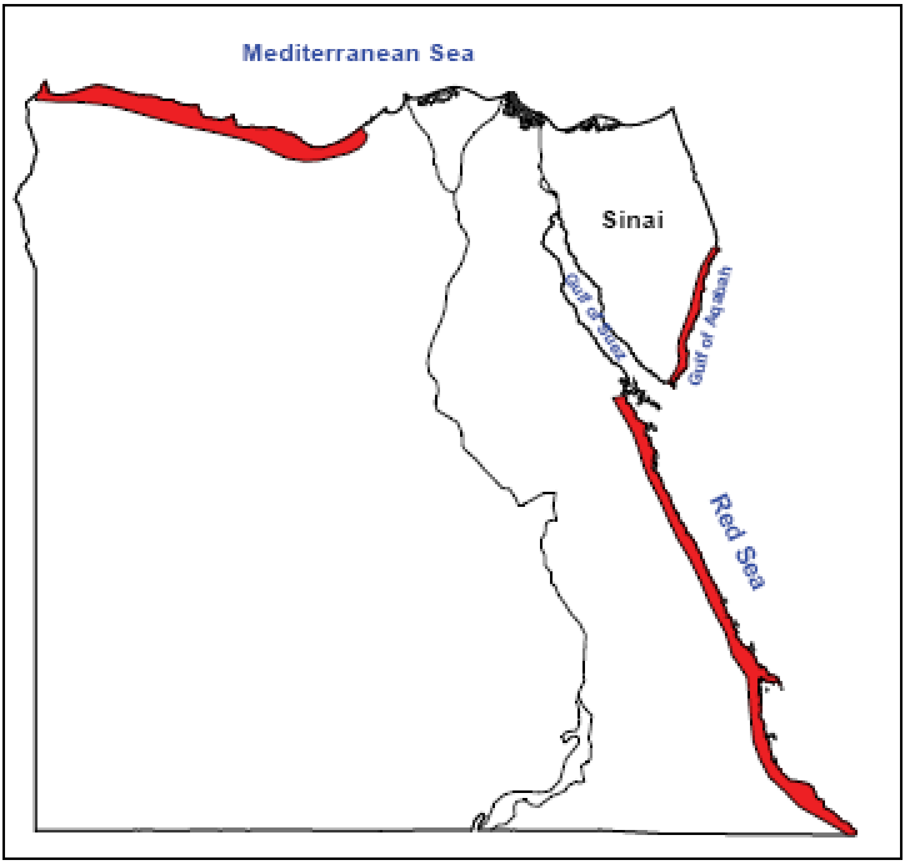


Figure 11 Areas facing water shortage **(INECO, March 2009)**

[17] INECO. (March 2009). *Institutional framework and desicion-making practices for water management in Egypt.* International Consultants Egypt.

2.1.2. Water situation in the Red Sea region

2.1.2.1. Geographical characteristics

The total length of the Egyptian Red Sea coast is about 1,705 km. Of this, 760 km is Red Sea coast and 945 km is the coastline of the Gulfs of Suez and Aqaba. Some industries are located along the Red Sea coast, in Hurghada, Safaga, and Quseir. The adjacent land area of the Red Sea is mostly arid, desert or semi-desert regions with no major river inflows. Further inland, the desert regions are bordered by extensive mountain ranges. [18]

The Egyptian Red Sea region is located in an arid zone with extremely hot weather in the summer. The air temperature in the northern region is in the range of 6 – 39°C at the Suez Canal and it is slightly warmer in the southern region, which has a range of 13 – 42°C along Shalateen coast. Rainfall in the Red Sea region is extremely sparse and is usually localized in the form of short showers. The annual rainfall is in the range of 0 – 25 mm. [18]

2.1.2.2. Groundwater availability

2.1.2.2.1. Groundwater systems

D. Coastal Aquifer Systems

The Coastal aquifer systems are assigned to the Quaternary and Late Tertiary. They are found in the littoral zones along the Red Sea coasts in the form of scattered pockets. Along the Gulf of Suez, the main formation consists of alluvial Quaternary deposits. Miocene sandstone and Nubian sandstone formations also act as local aquifers. Groundwater is generally brackish. [18]

In the littoral area west of the Gulf of Suez, the strata of hydrogeological interest are the Miocene and the Nubian sandstone. Groundwater recharge occurs from local rainfall; while discharge takes place mainly through groundwater abstraction by wells. [18]

Locally, the fissured Upper Cretaceous and the Late Tertiary act as potential aquifers. Recharge is achieved mainly from local rainfall (Gebal Elba). Discharge, on the other hand, takes place in the form of groundwater flow (natural) and abstraction through manmade shallow wells. [18]

[18] (USAID), T. U. (JUNE 2008). *LIFE Red Sea Project - Best Environmental Practices for Desalination Plants in the South Red Sea Region of Egypt.* Chemonics International.

E. Hard Rocks

Hard rocks are outcropping in Southern Sinai and the Eastern Desert. The permeability of the smaller fissures diminishes with depth. Hence, groundwater below about 100 m depth is only expected in large regional fractures. The aquifer is essentially recharged from its extension in Sudan, and, locally from rainfall in the Sinai. [18]

Shallow groundwater is expected to be recharged either through seepage from valleys or by direct infiltration from rainfall. The volume of groundwater in storage is expected to be very limited, and quality is expected to show large variations. [18]

Underground water related to the Red Sea is generally higher in salinity than sea water. This is due to the dominating underlying salt and evaporate formations. Salinity between 50,000 – 60,000 ppm is normally expected at depths more than 30 m. [18]

F. Nubian Sandstone

The Nubian Sandstone aquifer system is assigned to the Paleozoic–Mesozoic. It occupies a large area of the Western Desert, parts of the Eastern Desert, and Sinai. Groundwater can be found at very shallow depths, where the water bearing formation (horizon) is exposed; or at very large depths (up to 1,500 m), where the aquifer is semi-confined. The aquifer transmissivity is generally medium to low, varying from 1,000 – 4,000 m^3/day. [18]

The Nubian Sandstone aquifer system contains a huge amount of non-renewable groundwater dating back to the rainy period that occurred from 25,000 – 40,000 years ago. Groundwater quality is generally good (<500 ppm), except near the coastal regions and in Sinai. Groundwater recharge is limited (estimated at 500 million m^3/year) across the boundaries with Chad and Sudan. [18]

2.1.2.2.2. Groundwater potential

Present development schemes are confined to shallow wells dug in valley aquifer systems and desalination of groundwater. There is potential for further development, especially based on the Nubian Sandstone aquifer, through deep wells (200–500 m) and in the large valleys that drain into the Nile Valley and Lake Nasser. [18]

In addition to fresh groundwater, large amounts of brackish groundwater are expected to be available in the region. This requires proper assessment and prediction of possible changes in salinity as a result of development. One of the areas of special interest is the Red Sea coastal area, where a variety of aquifers are present. Signs of water availability are the flowing springs. [18]

2.1.2.3. Red Sea and Sinai storage basins of rainwater torrents

Figures 12 and 13 show the rainwater basins along Red Sea western coast and Sinai coasts on Suez gulf, Aqaba gulf and Mediterranean Sea.

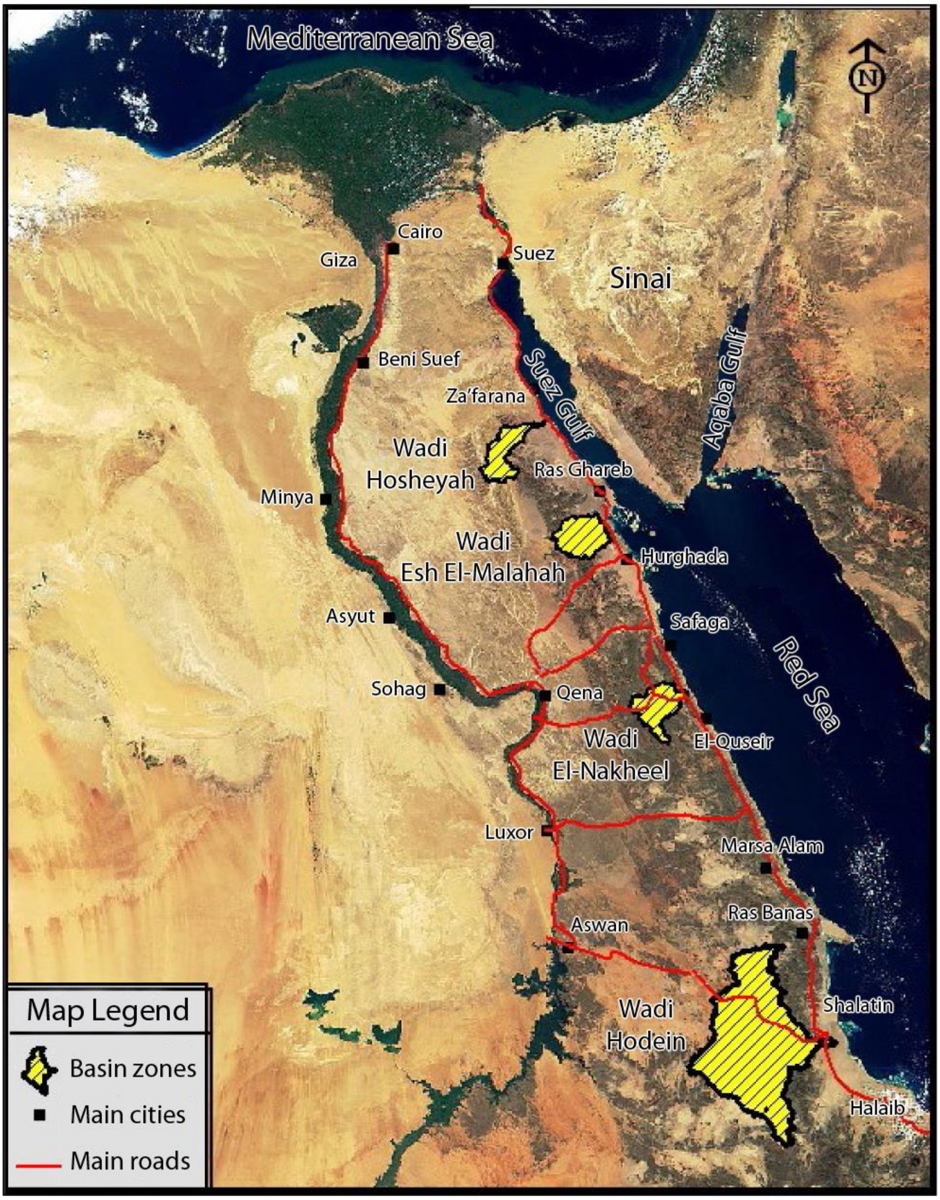


Figure 12 Red Sea rainwater basins **((NWRC), 2011)**

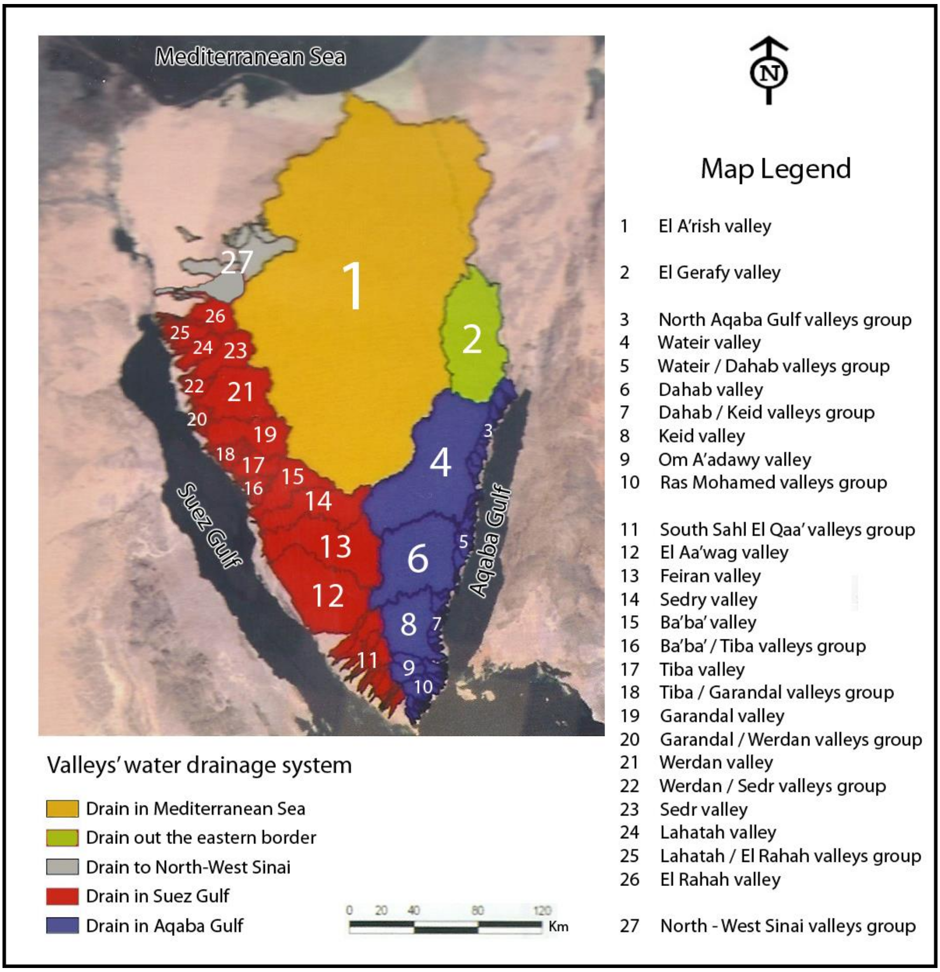


Figure 13 Sinai rainwater basins **((MWRI), 2010)**

2.1.2.4. Water usage in the tourism sector

In Egypt many of the tourism areas and activities are located in the Red Sea region. Tourism is a flourishing industry with increasing capacity, as the Red Sea region attracts tourists due to its nature and climactic conditions throughout the year.

Tourism development is considered to be one of the main development strategies for the Red Sea zone. Most tourism establishments on the coast meet their fresh water requirements through the desalination of sea water or brackish beach well groundwater. In addition, most Red Sea coastal towns have their own desalination plants.

	Nile water (m³)	Desalinated water (m³)	Ground water (m³)	Total (m³)
Ras Sidr	13,000	3,450	0	**16,450**
Abou Zeneima	4,000	0	0	**4,000**
Abou Redies	3,000	300	0	**3,300**
El Tor	0	0	15,000	**15,000**
Saint Catherine	0	0	75	**75**
Sharm el Sheikh	2,200	71,990	0	**74,190**
Dahab	0	7,000	0	**7,000**
Noweiba	0	9,000	0	**9,000**
Taba	0	5,200	0	**5,200**

Table 4 Distribution of South Sinai Fresh Water by Source, 2007 **(Services, 2007)**

Table 4 shows that all cities inland depend on groundwater. The cities on the eastern coast depend mainly on Nile water. All cities along Aqaba gulf depend mainly on Desalinated water from sea.

There is a great demand for fresh water in the Red Sea area to cope with planned development. Large sectors of the Egyptian coasts of the Red Sea, the Gulf of Aqaba and the Gulf of Suez have been developed into beach resorts. Next table shows an estimate of the water demand in the Red Sea and South Sinai through the year 2020.

Fresh water resources	2001		2020	
	Red Sea	S. Sinai	Red Sea	S. Sinai
Nile water pipelines (m³/d)	80,000	0	140,000	30,000
Fresh ground water (m³/d)	0	10,000	0	25,000
Sea water desalination (m³/d)	97,000	40,000	250,000	150,000
Estimated demand (m³/d)	500,000	125,000	1,000,000	600,000
Water shortage (m³/d)	323,000	75,000	610,000	395,000

Table 5 Assessment of fresh water demand and capacity in the Red Sea and South Sinai **(USAID, JUNE 2008)**

Table 5 shows that the Red Sea and South Sinai regions still depend mainly on desalination for water usage either in the past or the near future with a high accelerating rate. The second source is the Nile water pipeline network. The last source is groundwater with a low accelerating growth.

2.1.2.5. Implications of Sustainable Development

Tapping fossil aquifers is associated with many problems beyond the huge investments involved and their sustainability. For example salt accumulations in surface soil layers and/or underlying aquifers cannot be neglected in any long-term development project. Non-renewable or fossil groundwater resources should generally be carefully managed and saved as a strategic reserve for emergency or short-term use.

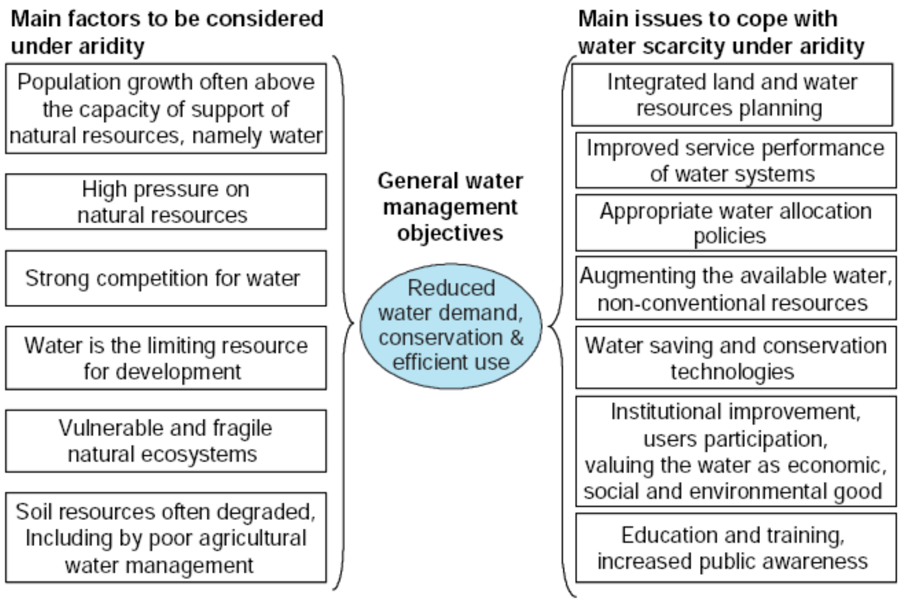


Figure 14 General framework for coping with water scarcity due to aridity: Main factors, objectives and issues **(Pereira, Cordery, & Iacovides, 2009)**

2.1.3. Environmental, Economic and Social Impacts of groundwater Overexploitation

Aquifers in arid areas depend on the occasional storm and flood events that may occur, so their development and use should be quite prudent since their sustainable operation is often questionable. The sustainability of groundwater resources in the arid zone is a serious long-term concern and continuous monitoring and evaluation should guide the management of these aquifers.

Water shortage could easily result from groundwater mismanagement, even in regions where shortages could have been avoided and a balance between supply and demand could be achieved. Groundwater abuse and misuse in water scarcity regions has far reaching environmental and economic consequences and comprehension of this is quite crucial in coping under conditions of limited water availability. Effective water resources management is thus essential to avoid human-induced water shortages.

2.1.3.1. Main environmental impacts

- Lowering of the groundwater level.
- Increased energy consumption.
- Reduction of well yield.
- Depletion of spring discharges.
- Reduction of stream base-flows.
- Drying of wetlands.
- Disturbance of natural flor and fauna affecting biodiversity.
- Degradation of groundwater quality.
- Seawater intrusion in coastal aquifers.
- Land surface changes due to subsidence.
- Changes in water used to support the natural ecosystems.

2.1.3.1.1. Groundwater level

A combination of factors, including land use, technology (well, borehole, pumping plant), geology, hydrology, hydrogeology, and demography conspire to create problem areas. Simple case studies may refer to the lowering of groundwater levels below shallow wells, leaving them dry, or to the reduction of recharge due to the building of a new dam in an aquifer recharge area. [1]

Yet others refer to groundwater level drop due to increased pumping, caused by the sudden expansion of population at certain locations in response to tourism development or work opportunity. The examples indicate that vulnerability varies over space and time and it relates to the ability of users and communities to access alternative water sources and develop new water supply schemes.

In such an event, wells may have to be deepened, provided the aquifer extends to greater depths. Furthermore, the existing pumping equipment may need to be replaced if the new depths are beyond their working performance range. Improper maintenance of wells and of the pumping machinery may compound the problem of water inadequacy; especially under conditions of falling water levels.

2.1.3.1.2. Water Quality Deterioration

Overexploitation of aquifers during periods of water scarcity causes much steeper hydraulic gradients towards wells. These conditions favor increased groundwater contamination from the ground surface especially if the area is agriculturally developed. This quality deterioration could affect the use of groundwater for drinking purposes. The pollutants that cause the most concern are nitrates and to a lesser extent pesticides, heavy metals and organic compounds. Outbreaks of disease may occur as people use unprotected, traditional sources or sources invaded by inferior quality groundwater. [1]

2.1.3.1.3. Land Subsidence and Land Collapse

Intensive groundwater use, resulting in depletion of aquifer storage and lowering of the water table, under certain aquifer conditions, may cause land subsidence and the development of new sinkholes in the case of carbonate aquifers. [1]

Figure 15 Sinkhole formed due to drawdown of the aquifer at Ras El-Ain, Syria **(Pereira, Cordery, & Iacovides, 2009)**

Land subsidence occurs in areas of serious lowering of the water table where the lithology of the underlying aquifer consists of poorly compacted sands and clays. The dynamics of land subsidence caused by a declining water table depend on the intensity of groundwater abstraction, the extent of decline of the water table, the geological structure of the aquifer, the soil compressibility properties and the thickness of the aquifer. [1]

Groundwater withdrawal has little effect on aquifers consisting of solid and coherent rocks or unconsolidated gravel beds and sandy rocks that are non-compressible. In contrast, clayey soils, silts and peat have the largest susceptibility to compression and consolidation. Similarly, aquifers exhibiting inter-bedding of quite compressible clayey rocks with sand and gravel or other permeable formations are liable to land subsidence when subjected to substantial groundwater withdrawals. [1]

2.1.3.1.4. Stream Base-Flow Reduction and Drying of Wetlands

The presence of wetlands is normally associated with the presence of surface stream base-flow, or due to a high water table associated with a local lowland area. De-watering of the local aquifer causes a lowering of the water table and a reduction of stream base-flow resulting in the drying of wetlands. A drop of the water table will result in vegetation withering and drying up.

This impact is most pronounced in the case of wetlands and riparian vegetation belts. Some local endemic species may be affected or may even disappear. The fauna associated with the affected vegetation and wetlands suffer equally. Soil fauna and flora are also impacted. Overall, biodiversity may be affected to a large extent.

2.1.3.2. Economic and Social Impacts

The quest for water in areas of water scarcity or under a prolonged drought episode results in intensive groundwater extraction. This increased groundwater pumping produces many undesirable environmental impacts that in turn lead to serious economic consequences.

Capital investment in well construction and pumping plant may be totally lost if the well runs dry, unless it can be deepened. Larger capital investment will be required for wells of increasing depth. Additional costs will be incurred where yields decrease and escalating recurrent costs will be associated with pumping from greater depths. The same apply in the case of intrusion of water of inferior quality with the consequent abandoning of wells. Large economic costs are also associated with measures to re-establish equilibrium where the unbalanced exploitation of aquifers led to such deterioration. [1]

Economic and social costs are also very high when the over-use of aquifers, coupled with uncontrolled land uses, facilitates the contamination of aquifers, so making them inappropriate for domestic and other high quality-requirement uses. Then quite costly water treatment to free water from nitrates, heavy metals and other substances have to be practiced, leading to higher costs for the water delivered to users. Social costs are particularly evident when poor urban and pre-urban populations need to search for other water sources.

Large economic and social costs also accrue from land subsidence produced by lowering of water tables. Roads, houses and other infrastructures may be highly affected when uneven ground conditions occur due to differential land subsidence. Costs are associated with the repair of houses and buildings, roads and hydraulic infrastructures. Surface water conduits may have to be totally rebuilt. Additionally, economic activities may be very much disturbed causing serious problems for poor families.

The environmental costs of wetland diminution and landscape change are high but very difficult to assess in economic terms. Impacts are more evident when rare vegetation and animal species are endangered, when the “green” landscape constitutes an almost unique ecosystem in an arid or semi-arid zone. Economic consequences are easier to evaluate when human populations make use of such oases or natural green areas.[1] The environmental impact of any groundwater management plan on wetlands and riparian ecosystems should be taken into account.

2.2. Development statistics for existing and expected resorts in the Red Sea region

2.2.1. Tourism development in Egypt

The geographic position of Egypt, its natural assets and old civilization have been the basis for the development of tourism, where the combined effort of the State and the public was concentrated. In 2005 the total number of visitors was estimated at 8.7 million. [15]

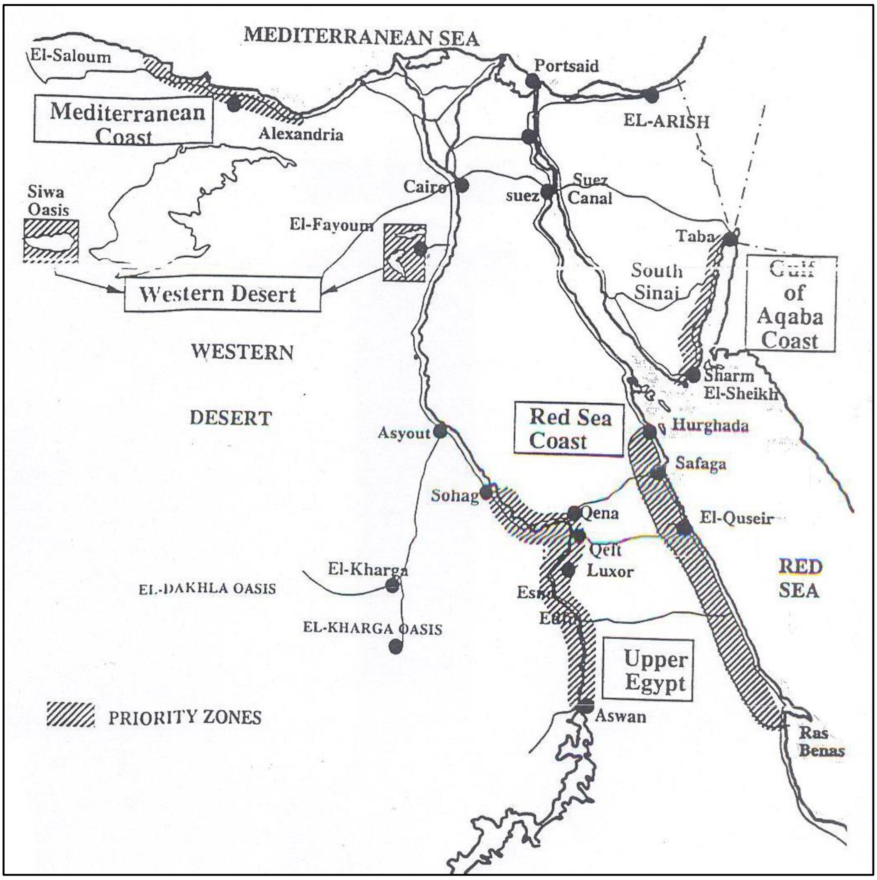


Figure 16 Egypt's priority zones for Tourism development **((TDA), 1995)**

Figure 16 shows that Red Sea region, including the western coast of Red Sea and the eastern coast of South Sinai, is one of the priority zones for tourism development in Egypt.

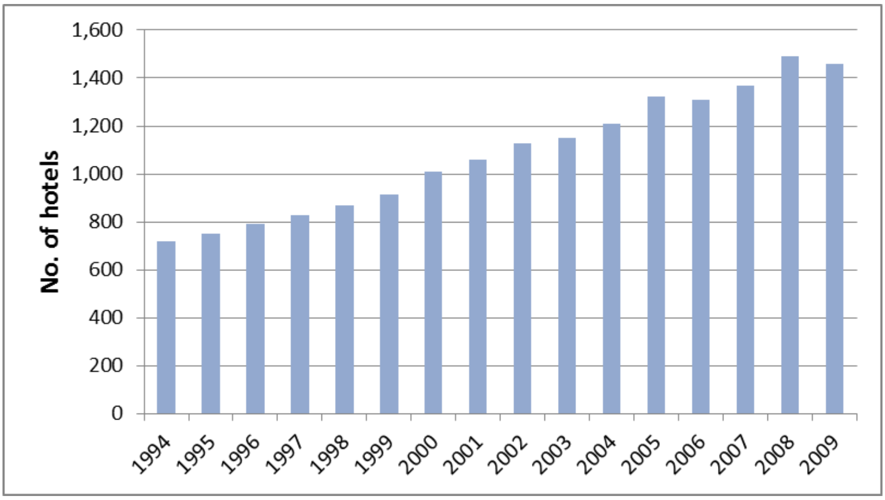


Figure 17 Hotel growth in Egypt by year **(Hotels Supervision Sector, 2009)**

Figure 17 shows that hotels have almost a regular growth in Egypt.

Over the past few years, South Sinai has become one of the major tourism destinations in Egypt; and today, it occupies top position, on equal-footing with the Red Sea Coast.[19] As illustrated in Figure 18, South Sinai holds the largest share of hotel residents in the main six tourist destinations of the country (Cairo, Red Sea, South Sinai, Luxor and Aswan), surpassing that of the Red Sea region.

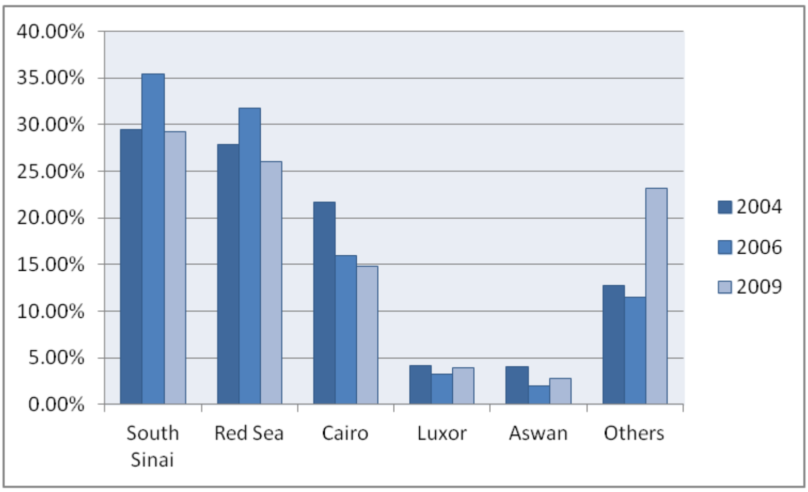
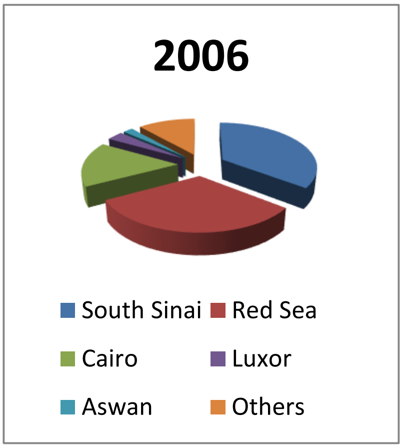


Figure 18 Distribution of Hotel Residents by Main Tourism Destinations by year, data only from **(Services, 2007) (Hotels Supervision Sector, 2009)**, graphed by researcher

[19] Services, P. I. (2007). *South Sinai Regional Development Programme - Inception Report for Sustainable Tourism Development of South Sinai (EuropeAid/12290/D/SV/EG).* London: PA Consulting Group.

Tourism is known as a highly volatile industry. It is strongly affected by erratic events, such as Sept. 11th, 2001 Attacks on the United States; the escalation of the Palestinian-Israeli conflict (2000-2002); the War on Iraq (2003); and the terrorist acts in Sinai (Oct. 2004/2005). The economic impact of the downturn in tourism activity as a result of these upheavals is quite substantial, especially in case of high frequency and severity of occurrences, which do strongly influence the risk perception of prospective travelers and tourism expansion.



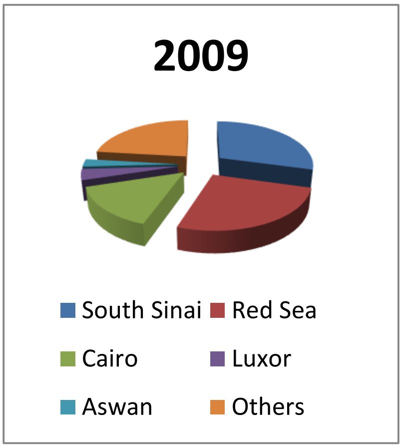


Figure 19 Comparison charts for distribution of Hotel Residents by Main Tourism Destinations in 2006 / 2009, data only from **(Services, 2007) (Hotels Supervision Sector, 2009)**, graphed by researcher

Figure 19 shows that the Red Sea and South Sinai regions have the highest rates of hotel residents in Egypt, but these ratios became lower in 2009 than their values in 2006.

2.2.2. Red Sea Tourism development plan

The Red Sea area is about 200,000 kilometers, representing a fifth of the Egyptian land stretching from Abul Darah, located 110 km south of Suez and extending to Halaib near the Sudanese border. The area stretches between the beach and the parallel coastal road and the mountain range passing through a number of urban centers such as: Ras Gharib, Suez, Hurghada, Safaga, El Quseir, Marsa Alam, Ras Banas, Bernice, Shalatin and Halaib, as well as a number of islands in front of the beach. [20]

Sources of water: the underground water is limited, so treated water is used in agriculture depending on the desalination of sea water.

[20] (TDA), T. D. (1995). *Tourism development plan for the Red Sea region (Arabic).* Giza: Tourism Development Authority (TDA).

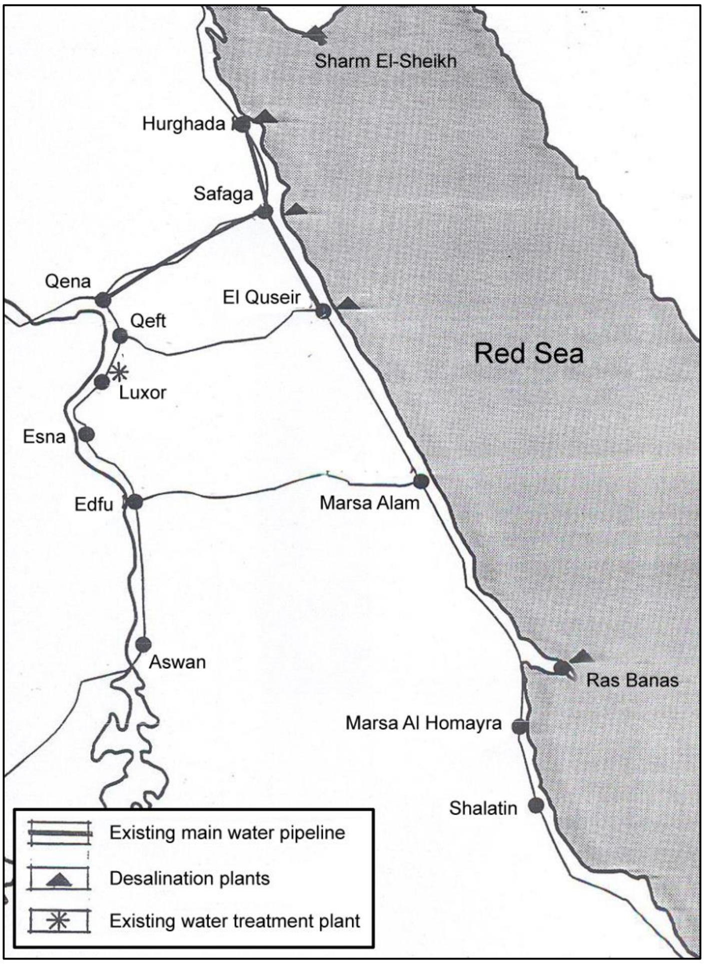


Figure 20 Water network along the western Red Sea coast **((TDA), 1995)**

It had been possible to divide the region to smaller sectors with the theory of Sub System represents homogeneous sectors, despite the different environmental resources of each of them, by integrating tourism activities within the sector, achieving optimum utilization of natural resources and the economic savings of the infrastructure elements and organizing touristic urbanism within the sector and is integrated with other sectors.

	2007	2012	2017
No. of resorts	100	75	50
No. of rooms	20,000	15,000	10,000

Table 6 Growth expectations for the Red Sea area in accordance with the National Project for South Egypt **((TDA), 1995)**

The table shows that the Red Sea region has an expected declining growth.

The region is divided into 9 sectors as follows: [20]

- Suez / Zafarana, 120 kilometers long.
- Hurghada / Ras Gharib, 160 kilometers long.
- Hurghada / Safaga, 60 kilometers long.
- Safaga / El Quseir, 80 kilometers long.
- El Quseir / Marsa Alam, 138 kilometers long.
- Marsa Alam / Abu Ghosoun, 80 kilometers long.
- Abu Ghosoun / Bernice, 72 kilometers long.
- Bernice / Shalatin / Halaib, 250 kilometers long.
- Group of islands in front of the sector.

2.2.2.1. Hurghada - Safaga sector

Figure 21 shows the tourism development plan for Hurghada - Safaga sector:

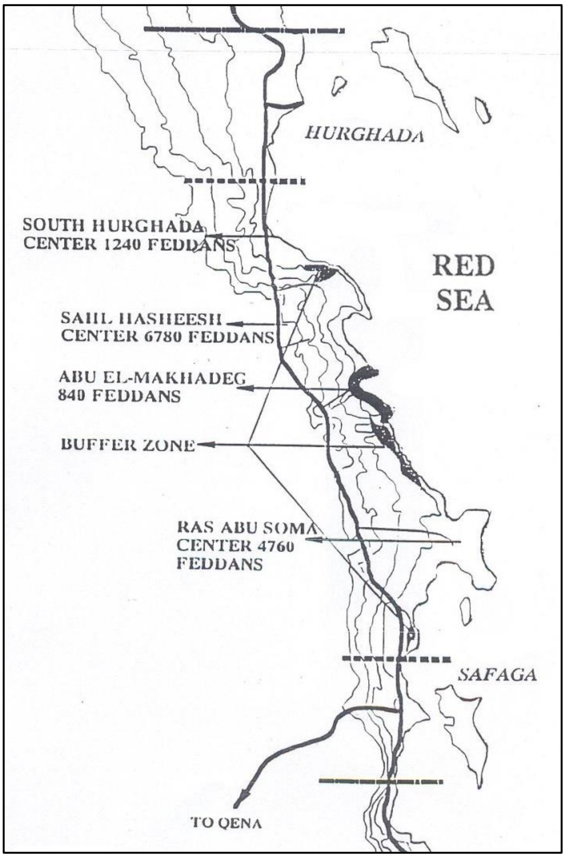


Figure 21 Tourism development plan in Hurghada - Safaga sector **((TDA), 1995)**

2.2.2.2. Safaga - El Quseir sector

Based on the selection determinants of areas suitable for tourism development of sector Safaga/El Quseir, the areas suitable for development is concentrated in four main areas: [20]

- The Kalawy area: 35 feddans.
- The mangrove area: 250 feddans.
- Wadi Noah area: 70 feddans.
- South Wadi Noah area: 565 feddans.

The total of these areas is about 1000 feddans along a shore of 11 km and based on the potential of the region and its comparative advantage of tourism compared to Safaga and Hurghada, the level of accommodation and tourism service will not exceed 3-4 stars therefore the capacity of areas suitable for tourism development was estimated about 15 thousand guests on the basis of overall density of 15 persons / feddan, with a total hotel capacity about 8000 rooms for this region. [20]

2.2.2.3. El Quseir - Marsa Alam sector

Figure 22 shows the tourism development plan for south El Quseir:

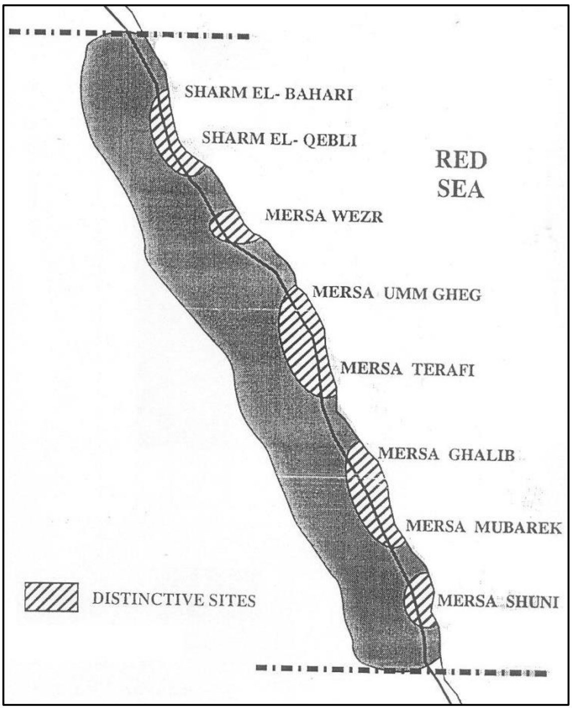


Figure 22 Tourism development plan in south El Quseir **((TDA), 1995)**

Three areas suitable for use have been identified: [20]

- Mersa Agalah area: 1500 feddans.
- Northern Marsa Alam area: 6500 feddans.
- Mersa Terafi area: 6600 feddans.

For Marsa Alam area: [20]

- Providing a touristic center in the proposed city with area of 650 feddans.
- A capacity of 10 thousand rooms from 3 to 4 stars.
- Providing two secondary touristic centers, the first at a distance of 8 km north of the city having area of 500 feddans with a capacity of 4500 rooms, and the second at a distance of 12 km south of the city having area of 300 feddans with a capacity of 2500 rooms.

2.2.2.4. Marsa Alam - Abu Ghosoun sector

Figure 23 shows the tourism development plan for Wadi El-Gemal:

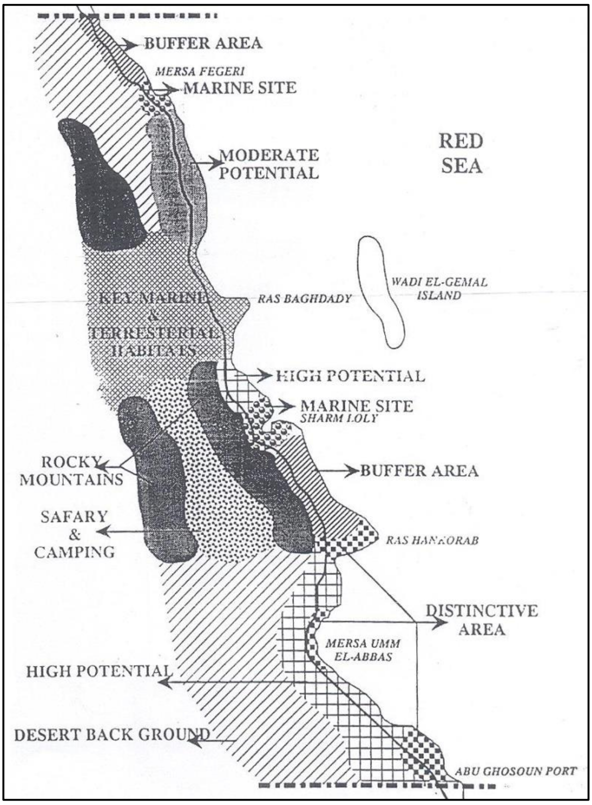


Figure 23 Wadi El-Gemal potential areas for Tourism **((TDA), 1995)**

2.2.2.5. Bernice - Shalatin - Halaib sector

Figure 24 shows the tourism development plan for Ras Banas:

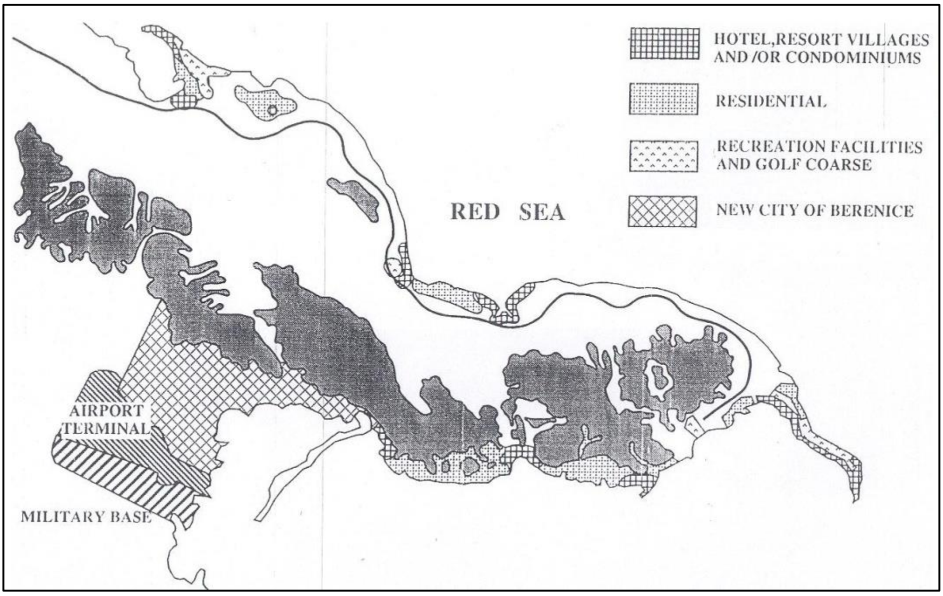


Figure 24 Ras Banas potential area for Tourism **((TDA), 1995)**

Long-term development plan to 2017: Establishment of 1500 hotel rooms with all the complementary services. [20]

Development sectors and the expected capacity: [20]

- First sector: about 1000 rooms.
- Second sector: about 300 rooms.
- Third sector: about 400 rooms.
- Fourth sector: about 200 rooms.
- Fifth sector: about 500 rooms.

	5-star		4-star		3-star		2-star		1-star		Not classified	
	Hotels	Rooms	Hotels	Rooms	Hotels	Rooms	Hotels	Rooms	Hotels	Rooms	Hotels	Rooms
Hurgada	20	9,598	41	15,856	51	9,875	24	2,259	14	897	13	3,089
Abu El Makhadeg /Abu Soma	11	4,200	11	3,208	4	1,101	1	100	0	0	5	1,835
Safaga /Quseir	2	552	17	4,475	16	2,952	7	557	3	234	17	2,951
Marsa Alam			9	2,672	17	2,296	5	253	0	0	17	1,231
Total	33	14,350	78	26,211	88	16,224	37	3,169	17	1,131	52	9,106

Table 7 Red Sea Hotel/Room capacity by destination, 2009 **(Hotels Supervision Sector, 2009)**

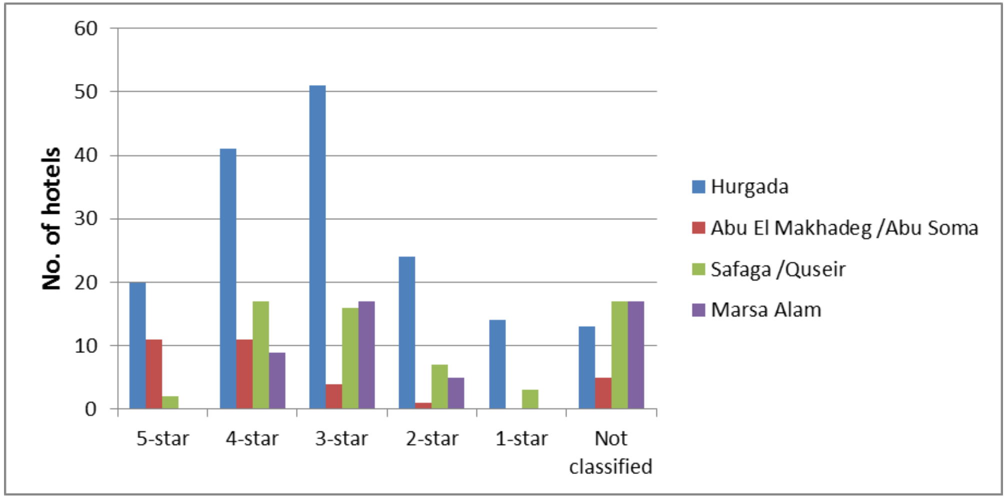


Figure 25 Red Sea Hotel capacity by destination, 2009 **(table above)**, graphed by researcher

Table 7 and Figure 25 show that Hurghada had the highest room capacity along the western Red Sea coast in 2009. Safaga/Quseir is the next and Marsa Alam comes in the third rank. The 3-star and 4-star hotels are the highest in the region.

2.2.3. South Sinai Tourism development plan

The growth in hotel capacity in South Sinai reflects the rapid expansion of the region as a tourism destination since approximately 1990. In 1989 there were just 13 hotels in the region with a total of 1,150 rooms. In 2007, there are 233 hotels with almost 48,000 rooms. [19]

	2007	2012	2017
No. of resorts	233	315	400
No. of rooms	47,843	64,900	81,990

Table 8 Growth expectations for South Sinai **(Services, 2007)**

Table 8 shows that the Red Sea region has an expected accelerating growth.

According to the TDA's regional office located in Sharm el Sheikh, there are at present nine touristic sites (in effect, zones) between Taba and Nuweiba designated for future development by the TDA, all of which are limited. There are 12-14 hotel projects in each zone - some sites are beach-side only, others have back-land as in Na'ama Bay in Sharm. Eight of the nine are located at the following places: Taba, Moqbella, El Mahashy El Aala, El Reviera, El Hamirah, El Mahashy El Asfal, El Malha and Om Mrikha. Near Sharm el Sheikh itself, there are two zones; one is at Montazah and is an integrated zone currently under development, and one is at Nabq which is designated as a limited site. [19]

TDA is also active on the Gulf of Suez coast. In Ras Sidr town, where there is an emerging domestic tourism destination of considerable importance and potential, there is government land in the urban area of course, but to the north there are two limited TDA zones at Ras Masala and Ras Deheza. South of the urban area there are 3 further TDA limited zones, at Ras Mattarma, Nekhela and Ras Malam. [19]

The region had been divided into touristic sectors each represents a homogeneous region in terms of physical characteristics. These sectors can be considered areas of integrated development; each includes a group of touristic sites based on functional hierarchy so as to provide main services and facilities to serve the sector as a whole as efficiently as possible.

Benefit also from taking into account the theory of "Touristic-backward" for each sector, which represents the depth of tourism potential and comprehensive development in the mountain valleys and oases serving tourism in each sector.

The Gulf of Aqaba is considered one of the integrated environmental and natural touristic areas, which suits the international and local touristic uses. It also includes various touristic patterns which provide permanent and temporary touristic accommodation. These patterns are: [21]

- Integrated touristic areas, in Moqbella, El Reviera, Dahab and El Montazah.

- Centers for touristic activities (resorts), in Moqbella, El Mahashy El Aala, El Malha and Nabq.

- Areas for establishing outstanding touristic projects, in El Homira.
- Areas with limited possibilities, for private touristic villages.
- Wadi El Marakh, classified to provide staff housing complexes.

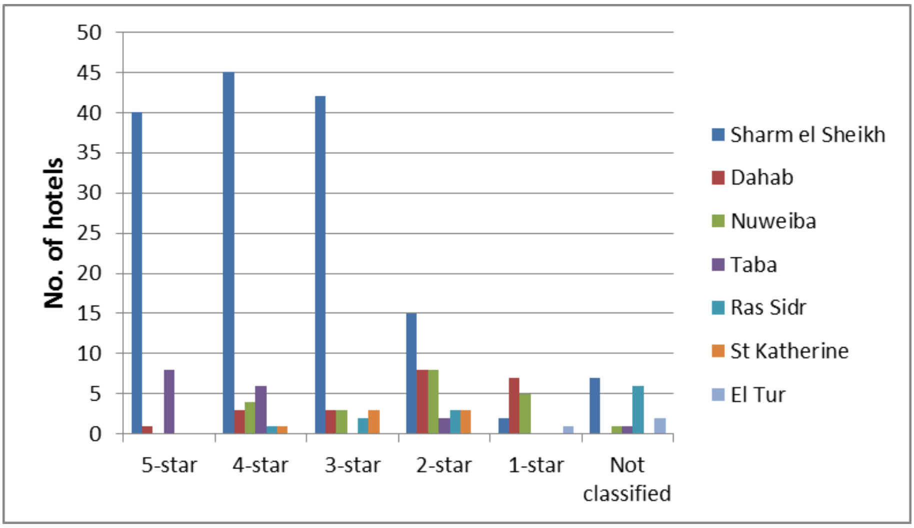


Figure 26 South Sinai Hotel capacity by destination, 2006, data from **(Services, 2007)**, graphed by researcher

By comparing Figure 26 with Figure 27, it is clear to observe that Sharm El-Sheikh is still the highest in room capacities of almost all hotel rates. Nuweiba / Taba region has an accelerating growth in room capacity reaching the second rank in South Sinai. Dahab comes in the third place. The 3-star and 4-star hotels are the highest in the region.

[21] (TDA), T. D. (1998). *Comprehensive tourism development plan for the Gulf of Aqaba - South Sinai (Arabic).* Giza: Tourism Development Authority (TDA).

	5-star		4-star		3-star		2-star		1-star		Not classified	
	Hotels	Rooms	Hotels	Rooms	Hotels	Rooms	Hotels	Rooms	Hotels	Rooms	Hotels	Rooms
Sharm el Sheikh	46	23,143	65	19,917	50	7,712	17	1,381	2	66	20	3,296
Dahab	2	347	3	549	4	711	12	675	7	195	12	327
Nuweiba /Taba	8	3,333	9	1,412	22	903	8	396	5	185	19	1,455
Ras Sedr	0	0	3	761	7	761	2	138	0	0	10	900
El Tor /St. Catherine	0	0	0	0	4	434	4	332	2	47	0	0
Total	56	26,823	80	22,639	87	10,521	43	2,922	16	493	61	5,978

Table 9 South Sinai Hotel/Room capacity by destination, 2009 **(Hotels Supervision Sector, 2009)**

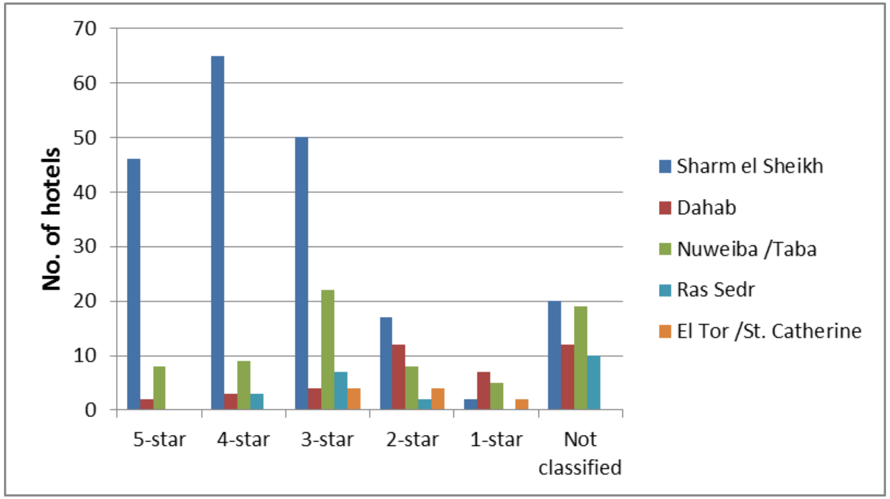


Figure 27 South Sinai Hotel capacity by destination, 2009 **(table above)**, graphed by researcher

2.2.3.1. Taba sector

The sector is located at the north end of the Aqaba Gulf, where it connects up to Israel to the north, through the Naqab desert, and stretches until Ras El Barqa to the south. The sector is divided into centers with various and different characteristics as follows: [21]

- Taba center.
- El Marakh center.
- Moqbella and El Homira center.
- El Mahashy El Aala center.
- El Riviera center.

2.2.3.2. Nuweiba sector

Nuweiba is located in the northern half of the Aqaba Gulf from El Barqa mountain northward to South Wadi Tarabin southward, between the Aqaba Gulf on the east and the highlands of southern Sinai on the west. Within the former limits, the sector contains four development centers: [21]

- El Hamirah center.
- El Mahashy El Asfal center.
- El Malha center.
- Om Merikha center.

2.2.3.3. Dahab sector

Dahab is located in the middle sector of the Aqaba Gulf from the city of Nuweiba northward to Abu Galum southward, a protected nature reserve, between the Aqaba Gulf on the east and the highlands of southern Sinai on the west. Within the former limits, the sector contains one development sector: [21]

- Dahab center (integrated development)
  - The mouth of Wadi Hobik: An area of 450 feddans and the length of coastline equals about 3 km.
  - The mouth Wadi Omran (Al Megeizer): The length of the waterfront area stretches about 3 km and the total area equals about 200 feddans.
  - The mouth of Wadi Sokhn: Located at the entrance to Abu Galum protected zone with an area of about 450 feddans and a waterfront with a length of about 3.25 km while the maximum width reaches about 1 km.

2.2.3.4. Sharm el Sheikh sector (Nabq center)

Sharm El Sheikh is located in the southern part of the Aqaba Gulf from Wadi Keid to the north, a nature reserve, to the south convergence point of the Aqaba and Suez Gulfs at the end of Ras Mohammed, a nature reserve, between the Strait of Tiran and the islands of Tiran and Sanafir on the east and the highlands of southern Sinai on the west. [21]

2.2.3.5. South Sinai development plan until 2017

Zone	Center	Area (feddans)	Capacity until 2017 (rooms)
El Aqaba Gulf zone	Taba	643.6	3098
	Moqbella and El Homira	948.8	3679
	El Mahashy El Aala	928.6	3617
	El Reviera	1217	7200
	El Hamirah	350	2000
	El Mahashy El Asfal	650	2700
	El Malha	650	3796
	Om Merikha	146	2000
	Hobik	238	2000
	Dahab	1022	4900
	Nabq	2000	20000
	El Montazah	833	4000
Suez Gulf zone	North of Oyoun Moses	8100	2500
	South of Oyoun Moses	6200	2000
	Ras Dahisa	4500	4500
	North of Ras Mattarma	4000	2500
	South of Ras Mattarma	3300	2000
	Nakhela	5200	4500
	Ras Malaab	10200	5000

Table 10 Capacity expectations for South Sinai by centers **(Services, 2007)**

Table 10 shows that Nabq has the highest room capacity expectations in 2017 with 20,000 rooms. El Reviera comes in the second place with 7,200 rooms expected. The third rank include Ras Malaab, Dahab, Ras Dahisa, Nakhela and El Montazah with a range between 5,000 to 4,000 rooms expected.

Chapter conclusions

From this chapter, conclusions can be summarized as followed:

1. Although there is a great demand for fresh water in the Red Sea area to cope with planned development, the Egyptian Red sea region is considered one of the most regions in Egypt facing an extreme water shortage.

2. In 2020, water total capacity will reach 595,000 m^3/day in this region. While the total water demand is estimated to reach 1,600,000 m^3/day. This means an estimated water shortage of 1,005,000 m^3/day in the Red sea region by 2020.

3. Tourism development is considered to be one of the main development strategies for the Red Sea zone. Tourism development is the second largest water-consuming sector in the Red Sea governorate after agriculture, unlike south Sinai governorate where tourism development is the largest among other sectors.

4. Most resorts on the coast meet their fresh water requirements through the desalination of sea water or brackish beach well groundwater which require high initial costs and energy consumption.

Chapter three: Considerations for water efficiency in resorts during design and construction phases

3.1. Water efficiency in design phase
3.2. Water efficiency in construction phase

3.1. Water efficiency in design phase

3.1.1. The international criteria for designing eco-resorts

The ecotourism industry is at a crossroads in its development. In the last decade, it has generated much revenue for local and regional economies worldwide, provided new incentives for governments and local communities to preserve protected areas and species, and heightened over-all local awareness of the importance of conservation. [22]

However, it also has led to numerous problems, and placed undue pressures and threats on the natural resources that sustain it. From these often-costly lessons, the benefits of ecotourism can only be sustained through well-planned and carefully implemented projects that place the long-term wellbeing of the natural resources and local communities as a top priority.

So, the aim has been to provide a framework for the design, development and operations of future resorts such that they uphold the social and ecological integrity of their given environments, and thereby allow for sustained benefits from ecotourism without damaging or destroying the very natural resources on which they depend.

An eco-resort is an accommodation facility that satisfies at least five of the criteria listed below, three of which must embody the main principles of ecotourism; that of conservation of neighboring lands, benefits to local communities and interpretation to both local populations and guests: [22]

1. Helps in the conservation of the surrounding flora and fauna.
2. Endeavors to work together with the local community.
3. Offers interpretive programs to educate both its employees and tourists about the surrounding natural and cultural environments.
4. Uses alternative, sustainable means of water acquisition and reduces water consumption.
5. Provides for careful handling and disposal of solid waste and sewage.
6. Meets its energy needs through passive design and renewable energy sources.

[22] Mehta, H., Báez, A. L., & O'Loughlin, P. (2002). *International Eco-resort Guidelines.* Burlington, Vermont USA: The International Ecotourism Society.

7. Uses traditional building technology and materials wherever possible and combines these with their modern counterparts for greater sustainability.
8. Has minimal impact on the natural surroundings during construction.

9. Fits into its specific physical and cultural contexts through careful attention to form, landscaping and color, as well as the use of vernacular architecture.

10. Contributes to sustainable local community development through education programs and research.

3.1.2. Site Selection and planning

Careful, well-researched master site planning, and ecologically and socially conscious site design is crucial to creating harmony between tourism developments and environmental/cultural protection. Preserving the special characteristics of a place requires an in-depth understanding of the natural systems on the site, and the cultural responses to that environment's history, opportunities and constraints.

Therefore, the site planning and design for an eco-resort must first of all safeguard the sustainability and conservation of the area's natural assets and cultural heritage, and improve where possible on impacts that may already be present on the site.

3.1.2.1. Site Evaluations and Selection

The main aspects of site selection are discussed as followed:

- When locating an eco-resort, the quality of the surrounding cultural and natural environment, site access, sewage disposal, water supply and impact on the neighboring ecosystem should be considered. [22]

- Selection of the most adequate location for an eco-resort based upon a comparative analysis of alternative sites. [22]

3.1.2.2. Site Inventory and Physical Analysis

The main steps of Site Inventory and Physical Analysis are discussed as followed:

A. Climate

Careful analysis of the climatic factors of the site such as: [22]

1. *Temperature*
   - Monthly temperature variations: mean, maximum and minimum.
   - Temperature variations between day and night.
   - Frequency and mean duration of temperature extremes.
   - Location variations (north and south slopes aspects).

2. *Precipitation and humidity*
   - Monthly and yearly mean precipitation (measured in mm).
   - Identification of dry and rainy seasons.
   - Absolute and relative humidity.
   - Snow accumulations and disposition pattern.

B. Land

A detailed analysis of the following land characteristics: [22]

1. *Soils*
   - Dominant types of soil.
   - Resistance and compaction of soil: fitness for different types of foundation and construction.
   - Thickness of the different layers, degree of maturity, texture, strength, susceptibility to compaction, presence of organic materials, presence of alluvial soils, degree of permeability, fertility, rockiness, erosion, etc.

2. *Hydrology*
   - Presence of rivers, streams, wadis, lakes, marshes, reservoirs, or oceans (or distance to these features).
   - Subterranean waters.
   - Degree of water pollution.
   - Risk and frequency of flash floods.
   - Depth of water table.
   - Sources of potable water.
   - Potential for making use of hydroactive energy systems.
   - Soil recharge characteristics.

C. Vegetation

The analysis of local vegetation should include: [22]

- Native and introduced vegetation (exotic species).
- Endemic (peculiar to the area), characteristic and threatened flora species.
- Identification of focal (flagship) flora species (if any) from the ecotourism attraction viewpoint.
- Tolerance or susceptibility to different types of disturbance, such as trampling, fire, etc.
- Possible measures for regenerating local native vegetation.
- Potential for integrating site plan and architectural design with surrounding native vegetation and plant communities.

D. Cultural Features

A detailed analysis of cultural features should include: [22]

- Finding noteworthy local cultural elements, both past and present:
  - Traditional settlements.
  - Potential for integrating design with cultural environment.
- Understanding and respecting the main cultural elements and traits of the region.

3.1.2.3. Site Master Planning

Landscape architects, planners and architects (with a strong ecological and environmental foundation) are among the best trained to design a sustainable development in nature-based areas. They bear a special responsibility for the design of facilities that are to be developed in pristine, ecologically rich areas. The main aspects of master planning are:

- Using zoning to define allocation of areas for different uses and services based on the limits of acceptable change of the natural and cultural resources as well as other biophysical and climatic conditions. It must also support efforts to conserve the area’s natural and human resources and also contribute to enhance the quality of the ecotourist’s experience.

- For each of the zones, a specific density related to buildings and their primary uses should be planned. Examining relative merits of concentration versus dispersion, remembering that natural landscape values can normally be best conserved if the physical plan is carefully dispersed but also, inversely, knowing that by concentrating buildings and other structures helps leave more available undisturbed natural zones. Again, the challenge is striking the right balance. [22]

- The provision of multimodal access corridors and the use of road surfaces that are local and non-petroleum based so as to increase recharge of water and reduce runoffs.

- Minimizing impermeable surfaces when possible to reduce runoff and maximize groundwater recharge.

3.1.2.4. Site Design

The main aspects of site design are discussed as followed:

- In hot localities, if an area for swimming is included, a natural or semi-natural area should be considered, like a lake, artificial lake or the sea, but be sure there are no risks (noxious fauna, excessive sea waves or undertow, etc.) and avoid disturbance to aquatic fauna.

- Limiting the impervious cover of the ground to the minimum needed, especially around existing trees. Excessive areas for driveways should be avoided. A pervious surface, such as shell, turf, stone, brick or marl is recommended. [22]

- Trails should respect location, growth and expansion of the local flora.

- Vegetated swales should be used as a natural way of conveying concentrated runoff. Compared to closed structural systems, this open drainage increases plant variety, reduces need for irrigation water, reduces drainage velocity and erosion and needs less maintenance. [22]

- Managing runoff should be an important facet in eco-resort. If drainage controls are implemented at the beginning of site planning they can be integrated economically in the overall development. The concept is to capture rainwater from roofs and filter runoff from impervious pavements with minimal disturbance to natural drainage patterns.

- Directly channel runoff into water bodies or marshes should be avoided, conservation areas or other impervious surfaces without adequate filtration. Artificial runoff into existing natural swales should be diverted.[22]

3.1.2.5. Landscape Design

The following are some main aspects for landscape design:

- If native plant populations exist on a selected ecotourism site, it is crucial that they be conserved.

- Using salt-tolerant plants in areas close to the ocean. Salt from the ocean is transported in the air and deposited either on the vegetation or in the soil. Planting trees helps to lower the saline ground water table, thus protecting surface vegetation from excess salt. [22]

- Two goals for all planned plantings are that invasive species should never be introduced, and plantings should need only the minimum of maintenance, particularly in terms of water and trimming, once they are established.

3.1.3. Architectural Design

The responsive design of the eco-resort is at the core of offering the client an environmentally responsible travel experience. Existing eco-resorts worldwide have been able to demonstrate a remarkable level of sensitivity to both the local (site) environment and surrounding area.[9] The main aspects of architectural design are:

- Defining the easiest, fastest, most economical and least destructive way in which an eco-resort may be built, at the design stage. Making the most of all-available local natural resources and plan for long-term economic return.

- Creating an architectural style always consistent with an environmental philosophy and with the goals of ecotourism, avoiding design contradictions. Local traditional building forms and materials may provide clues to efficient and ecologically sensitive design. Also, negative environmental impacts should be minimized by designing an eco-resort with rational and economic use of space.

3.1.3.1. Context and Aesthetics

Using clues from the local landscape for materials, building forms and siting such as:

- Conceiving the shape of the roof to be a function of the site's precipitation regime (i.e. in places where it rains or snows abundantly, a pronounced pitch should be used; where it is predominantly dry use a flat or domed roof). The degree of overhang or extension of the roof beyond the building line can provide shelter from sun or rain.

- Whenever possible, previously disturbed sites should be developed. Redevelopment requires minimal disturbance of natural systems since the disturbed area may already be impacting the site. Suitable old or traditional buildings on the site should be converted into ecotourism facilities. Conversion of existing facilities is one of the lowest impact design techniques.

- Locating pasture and corral areas for any horses, camels, and other grazing stock away from natural sources of potable water or watersheds. [22]

- Integrating the resort into the surrounding landscape through the planting of various indigenous trees and shrubs whenever and wherever possible. Landscaping should be guided by the patterns of the existing natural landscape. Native vegetation (e.g. shrubs and trees) and rocks should be laid out in an informal, natural manner.

3.1.3.2. Areas and standards for Eco-resort Spaces

3.1.3.2.1. Built Area

The eco-resort development, including accommodation units, food and beverage services, and utilities should be contained within 20 percent of total surface. The remaining recreation, access, and maintenance facilities will be strategically located throughout the rest of the site. [9]

Table 11 shows the water-consuming zones in hotels. The water consumption in these areas is relatively dependent on their areas and equipment used.

Spaces		Unit	No. of Guest rooms									
			100		200		300		400		500	
			Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
Main toilets	Men	m^2	11,302	21,528	22,604	42,517	33,906	63,507	45,208	84,497	56,511	105,486
	Women		7,535	18,837	13,993	37,135	20,451	53,820	26,910	71,311	33,368	88,802
Main kitchen	Full		15,748	32,211	32,211	65,138	48,674	98,065	65,138	130,991	81,601	163,918
	Part		8,611	16,146	17,760	32,830	26,910	49,514	36,059	66,198	45,208	82,882
Secondary Kitchen			N.A.	N.A.	1,722	3,875	2,583	5,813	3,444	7,750	4,306	9,688
Staff toilets	Men		49	119	98	235	147	350	196	466	245	581
	Women		42	112	91	224	140	336	189	448	238	560
Staff lockers	Men		91	221	182	436	273	650	364	865	455	1,079
	Women		78	208	169	416	260	624	351	832	442	1,040
Laundry			4,306	9,149	8,611	17,760	12,917	26,372	17,222	34,983	21,528	43,594
Boiler room			4,844	8,611	9,688	16,146	14,531	23,681	19,375	31,215	24,219	38,750

Table 11 Areas of Hotel/Resort water-consuming spaces
(De Chiara & Callender, 1987)

3.1.3.2.2. Accommodation Density

The eco-resort room density varies depending on star rates: [21]

- A 3 star resort at 9 - 20 rooms/feddan.
- A 4 star resort at 6 - 17 rooms/feddan.
- A 5 star resort at 4 - 14 rooms/feddan.

3.1.3.2.3. Building height

Some investors may prefer a 2-story option because it has a smaller footprint, provides an interesting spatial arrangement, and can offer guests better views, particularly towards the sea or other vistas. The two floor limit may be exceeded for certain facilities such as roof patios or observation decks. [9]

3.1.3.2.4. Setback from Road and Shoreline (Coastal Site)

The legal setback for fixed buildings is 200m from the shoreline. The current guidelines suggest that 50m are required as a setback from the road. [9]

3.1.3.2.5. Room Components and Areas

The mix of components within the eco-resort unit should be of importance. If certain guidelines are not respected the room may not meet the basic needs of the guests. The following mix of spatial arrangements is proposed: [9]

- Entry and Storage: 15–20 percent
- Living Area: 30–40 percent
- Sleeping Area: 20–40 percent
- Bathroom/Dressing Area: 15–20 percent
- Total furniture: 33 percent
- Add another 30 percent for kitchenette (optional).

The minimum bathroom will have a combination tub-shower, a lavatory and a water closet. However, two lavatories may be right in the bathroom itself, they may be pulled out into a dressing area, or one lavatory may be placed in the bathroom and another outside the bathroom. Some hotels also introduce the bidet in bathrooms. [23]

3.1.3.2.6. Guest Circulation, Administration, and Services Areas

Eco-resorts are increasingly popular with the fast growing health and wellness market. This suggests that health facilities may be added. Facilities to be considered are: [9]

a) Office, hallways, lobby, storage.
b) Retail space.
c) Restaurant and lounge.
d) Resource center and reading room.
e) Health center (SPA).
f) Locker rooms with toilet facilities and showers.

3.1.3.2.7. Food and Beverage Area

The following are some main aspects for food and beverage area design:

[23] De Chiara, J., & Callender, J. (1987). *Time Saver for Building Types - Secnd Edition.* Singapore: McGraw-Hill.

- The final size of the restaurant will depend on the number of restaurants and if there are more than 1 sitting. Because of the mild Egyptian climate, 50–60 percent of the seating area may be on a covered outside deck. [9]

- The dishwasher is usually placed close to the dining room area so that the dishes can be disposed of as soon as the waiter or busboy enters the kitchen. The dishwashing area is, not only noisy but also a rather untidy operation, SO it must be kept fairly isolated from the actual cooking and serving area.

- It is an excellent idea to have toilets and washrooms for kitchen help, so that it isn't necessary for them to return to their locker rooms, which may be at some distance.

- In case there are several kitchens, preferably on a horizontal core, so that there is the possibility of vertical distribution of food from the preparation areas which would probably be on the lower level.

3.1.3.2.8. Laundry Facilities

A hotel laundry that does its own uniforms and flatwork (sheets, pillowcases, linens, etc.) requires a good-sized space for washers, dryers, drum ironers, and various pressing machines-each suitable for its own type of flatwork, uniforms and guests' laundry, and men's and women's wearing apparel.

Larger hotels will maintain their own cleaning department for dry cleaning and pressing of woolens and similar garments. Such a cleaning and valet service is usually a part of or close to the laundry area. [23]

3.1.3.2.9. Mechanical Spaces

The boiler or mechanical room will include the various pieces of equipment for heating and cooling as well as all the tanks and pumps to keep all the mechanical systems in operation.

3.1.3.2.10. Recreation Facilities

The mix of recreation facilities will depend on the preferences of the investor. Those that would be acceptable include tennis court, games area, and a saltwater swimming pool. The latter would have the most significant impact on the environment (pump and filtering); however, with the use of salt water, evaporation control, and solar generated motors this can be minimized. [9]

A saltwater swimming pool requires a surface area of 2–3 m^2 per swimmer. A hot tub should be adequate for 8–10 persons.[9] Some aspects for swimming pools are discussed as followed:

- The size, shape, and siting of swimming pools and equipment enclosures must be carefully considered to achieve a feeling of compatibility with the surrounding natural elements and the architecture of the resort.

- Carefully site the pool's plant room as this can minimize routing and ducting of services and increase heat recovery potential.

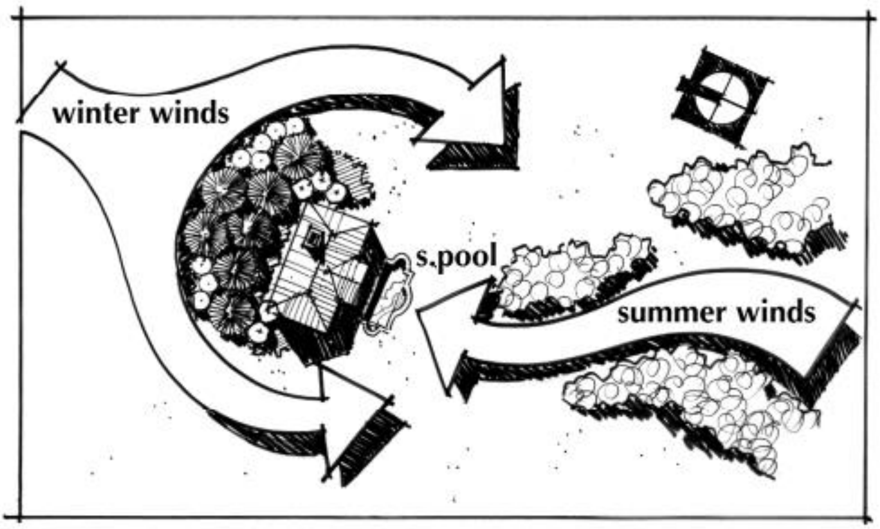


Figure 28 an example of a swimming pool orientation
(Mehta, Báez, & O'Loughlin, 2002)

3.2. Water efficiency in construction phase

3.2.1. The impacts of construction industry on the environment

Each year more than three billion metric tons of raw materials are used to manufacture construction materials and products worldwide. This is about 40–50% of the global economy's total flow. Inclusion of hidden flows is estimated to more than double the consumption of resources for materials. [24]

The building industry is the largest consumer of raw materials in the world today after food production.[13] A major guiding principle for the future should be a drastic reduction in the use of raw materials. This is best applied to the less common nonrenewable resources, but is also necessary for others.

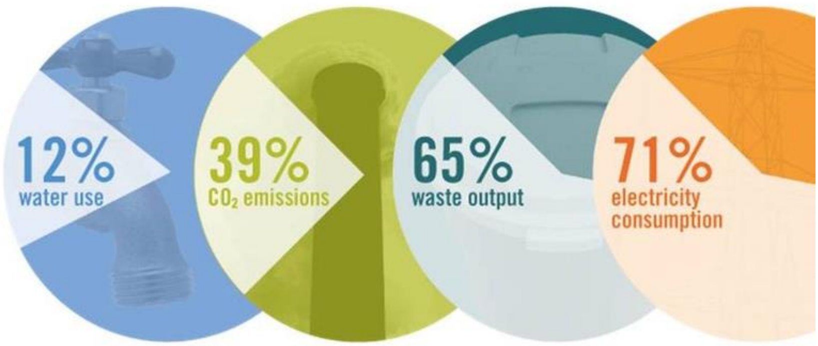


Figure 29 Building impacts **(Aquastat, 2005)**

Figure 29 declares the ratios of building construction effect on water usage (12%), Global Warming through producing CO_2 emissions (39%), waste production (65%) and energy consumption (71%).

Building materials and their potential performance have right from the very outset formed the starting basis for shaping buildings. Thus, the available technologies in stone, timber and bricks in earlier historical periods; in iron/steel and concrete since the nineteenth century and, very recently, in glass and plastics, have all influenced the appearance of buildings.

Traditional materials (such as timber, stone and bricks) find their application in new architecture. The science of materials has gone forward by leaps and bounds for traditional materials. Traditional materials have been perfected; new types and

[24] Calkins, M. (2009). *Materials for Sustainable Sites.* New Jersey: John Wiley & Sons, Inc.,.

composites of materials developed. Now, the new fabrication and jointing methods equally affect the design work of the architect.

For concrete and other materials, prefabrication (off-site processes) provides new opportunities. There exist various components which may be prefabricated: wall panels (cast as a whole or unitized from elements), volumetric units (modules or boxes), floor, ceiling and roof panels, sanitary blocks (WCs, bathrooms, kitchen units), partitions and others. Fabrication methods have to be selected; those for example for reinforced concrete panels include casting in horizontal position, casting in vertical position individually, or in batteries (i.e. in group forms). [8]

Most materials are made from nonrenewable resources, and their extraction disrupts habitats; impacts soil, air, and water; and affects human health either directly or indirectly through environmental damage.

Materials evaluation and selection may be one of the most confusing and controversial areas of sustainable site design, with multiple variables and many right and wrong answers. Other aspects of sustainable site design may be more easily quantified such as:

- **"What are the impacts?"** is the first question that must be asked in evaluating the environmental and human health impacts of a material or product. Taking a complete inventory of all environmental and human health impacts resulting from all inputs and outputs at all phases of a material's life cycle is a huge undertaking. This practice, called a life-cycle inventory (LCI), is a complex process best undertaken by material scientists and life-cycle analysts. And an inventory of impacts takes a certain expertise to interpret and will not provide answers in comparing materials without some idea of their relative importance. [24]

- **"What is the relative importance of the magnitude and risks of the impact compared to the other products impacts?"** is the second question and is most critical in successful evaluation of materials. Determining how much importance to assign to a given environmental or human health impact is challenging, and different weightings can produce highly variable results. Some emphasize that using resources efficiently, reusing them in closed-loop cycles, and eliminating waste is of paramount importance. Others claim that global climate change and reduction of carbon footprint is the most critical issue, and still others place greatest emphasis on reducing human health impacts of construction materials (Healthy Building Network). [24]

Material selection and specification remains a challenging, sometimes even contentious issue. Many designers experience difficulty understanding the full extent of environmental and human health impacts of building materials as they are not easily quantified. Complete and accurate information is elusive.
Life-cycle assessment (LCA), a thorough accounting of environmental and human health impacts of a material, is the best tool for truly evaluating materials.

Yet LCAs for materials and products used in site construction are limited, and wide variations between proprietary products, manufacturing methods and study boundaries can make comparisons difficult. [24]

Materials and products can cause negative impacts to ecosystems and the environment during all phases of their life cycle:

- In the materials acquisition phase, mining and harvesting practices can impact habitats and removal of vegetation increases runoff, loss of topsoil, and sedimentation of waterways. Waste piles from mining can leach heavy metals into the soil and ground and surface waters.

- Emissions and waste from manufacturing can impact air, water, and soil both near and far from the facility, as shown in Figure 30.

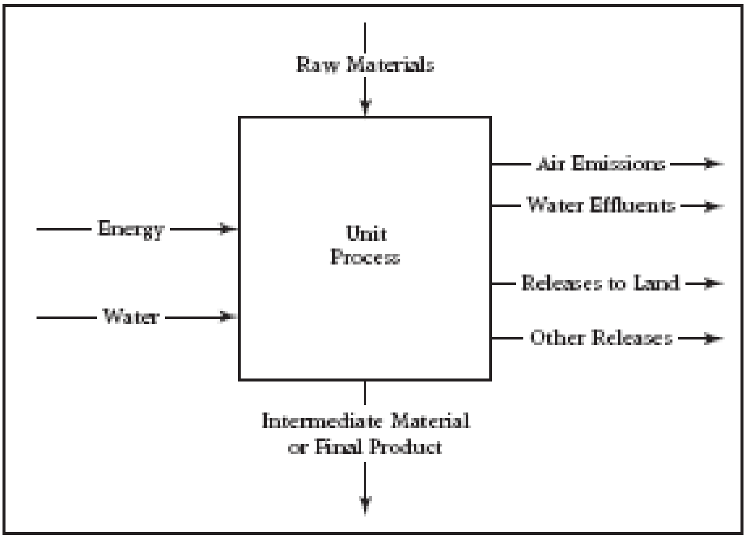


Figure 30 Material manufacture **(Calkins, 2009)**

- Transport of materials and products between all life-cycle phases uses nonrenewable fuel and releases emissions.

- Construction and maintenance of materials and products can involve solvents, adhesives, sealers, and finishes that off-gas VOCs or release toxic chemicals to the environment. Dust from unstabilized roads can impact air quality and adjacent vegetation and crops.

- Disposal of materials and products after their use can fill landfills, impact soil and water around poorly managed landfills, and impact air quality if incinerated.

In the building construction and operation phases there are the following possibilities for reducing the use of resources: [13]

- To build with an economic use of materials
- To minimize loss and wastage of materials on site
- To use the materials in such a way as to ensure their durability
- To maximize re-use and recycling of materials from demolition.

The inputs (resources, energy, and water) and outputs (emissions, effluents, and solid waste) that occur during the phases of a product's life cycle result in a variety of impacts that affect the health of our ecosystems, our planet, and us. The burning of fossil fuels and even some material processing activities contribute greenhouse gases to the atmosphere and acid deposition on water and land.

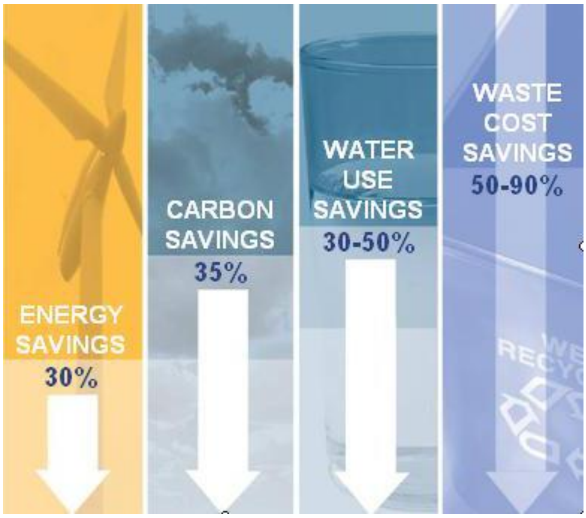


Figure 31 Average savings of green buildings **(Aquastat, 2005)**

Figure 31 shows that green buildings can have great savings for energy consumption (30%), CO_2 emissions (35%), water usage (up to 50%) and waste costs (up to 90%).

The appropriate materials for sustainable sites will vary by impact priorities, regional issues, project budgets, and performance requirements. Some will emphasize materials that conserve resources by being reused without remanufacturing, by being extremely durable, or by closing material loops with high recycled content and manufacturer take-back programs.

Others place great emphasis on low toxicity of products and emissions throughout their life cycle, while others may regard low ecological impacts or conservation of water as the highest priority.

Extensive quantities of water are consumed to produce some products and wastewater effluents from their processing can carry pollutants, acids, and heavy metals into the environment. It becomes is a disposal risk if not treated and remediated.

Material manufacturing processes that use large amounts of water or can result in water pollution are metal mining and primary processing, PVC production, stone working, brick making, and lumber processing. [24] Disposal of some materials, such as PVC pipes, can affect groundwater quality. Some manufacturers recycle wastewater back into manufacturing processes.

Product manufacturing activities use water, and effluent wastes that are released to water bodies reduce water resources through pollution. In addition, the use of impervious surfaces (such as concrete and asphalt) seriously reduces groundwater recharge, as do storm water management strategies that convey runoff away from the site.

The sustainability of an eco-resort can be determined, in part, by the choice of building technologies and materials used, and the level of care taken during the construction process. Unfortunately, many traditional resort architects and builders have not regarded ecological factors as their concern.

3.2.2. Construction Systems

Heavyweight construction systems are usually masonry and include brick, concrete, concrete block, tiles, rammed earth and mud brick. Lightweight construction uses timber or light gauge steel framing as the structural support system for non-structural cladding and linings. [25]

Table 12 shows how lightweight construction is better than heavyweight construction because of its general advantages. Lightweight construction has generally lower embodied energy and lower production impact. Lightweight construction has also better response to temperature changes. However, some lightweight materials, such as Aluminum, are exceptional.

When both systems are transported to remote sites, lightweight construction has more suitability for remote sites and lower site disturbance. However, both local lightweight and heavyweight materials are more recommended for their lower environmental impact caused by transportation.

[25] Reardon, C., & Downton, P. (n.d.). *5.5 CONSTRUCTION SYSTEMS.* Retrieved February 11, 2012, from Technical Manual - Design for lifestyle and the future: http://www.yourhome.gov.au/technical/fs55.html

Heavyweight construction	Lightweight construction
Generally has higher embodied energy.	Generally has lower embodied energy.
Improves thermal comfort and reduces operational (heating and cooling) energy use, when used in conjunction with passive design and good insulation.	Can yield lower total life cycle energy use, particularly where the diurnal range is low.
Is most appropriate in climates with high diurnal (day-night) temperature ranges and significant heating and cooling requirements.	Responds rapidly to temperature changes and can provide significant benefits in warmer climates by cooling rapidly at night.
Requires more substantial footing systems and causes greater site impact and disturbance.	Is preferred on remote sites with high materials transportation component.
Should be avoided on remote sites where there is a high transport component.	Usually requires more heating and cooling energy in cold to warm climates (where solar access is achievable) when compared to heavyweight construction with similar levels of insulation and passive design.
Is often quarried or processed with high impact.	Can have low production impact (eg. sustainably sourced timber) or high impact (unsustainably sourced timber or metal frame).

Table 12 Comparison between Heavy and Lightweight systems **(Reardon & Downton)**

3.2.2.1. Criteria for the selection of construction systems

Important factors influencing selection of construction system/s are:

- Durability compared to intended life span.
- Life cycle cost effectiveness.
- Availability of skills and materials.
- Source and environmental impact of all component materials and processes.
    - High renewable or recycled content systems are preferable where their durability and performance is appropriate for lifecycle (eg. fibre cement cladding and sustainably managed forest timber frames). [25]

  - Design for de-construction, recycling and re-use to amortize the impact of materials high in embodied energy or non-renewable resources where these materials are the best option.

  - Structurally efficient systems minimize overall materials use, transport and processing.

  - Use construction systems with known low wastage rates and environmentally sound production processes.

  - Specify materials with similar and appropriate life spans (eg. use fixings, flashings or sealants with a similar life span to the material being fixed). [25]

- Maintenance requirements.

  - Well maintained lightweight systems have durability equivalent to heavyweight systems.

  - Poor maintenance can reduce life span by up to 50 per cent, doubling materials consumption. Reliability of maintenance regimes for whole of life span is a critical consideration when selecting external cladding systems. [25]

- Lifecycle energy consumption.
- Distances required for transportation of components.

3.2.2.2. Aspects for the construction of eco-resorts

The following are the main aspects for the construction of eco-resorts:

- To be sustainable, your eco-resort should preserve natural resources on the site and minimize disturbance of the area's flora and fauna during construction. This can be achieved in part through utilizing traditional building materials and construction methods that can be found locally, reducing transport and pollution.

- Identify the most suitable building method for the site and type of project to develop, considering environmental, economic, cultural and time factors.

- Try to strike the right balance between use of traditional and modern building methods, including modular-designed prefabricated components that are designed to be easy to assemble or place on site (be careful to establish the exact environmental impacts and costs of bringing larger, heavier, completed prefabricated units onsite).

- The architect should incorporate traditional building technology in the design and construction of the eco-resort wherever possible. Examples of traditional technology include dried clay bricks, reeds, and other natural building materials using sun and wind, and use of handmade, human-powered tools, such as sieves, shovels and trowels. [22]

3.2.3. Materials Selection

3.2.3.1. Criteria for the selection of materials

The main aspects for selecting materials are discussed as followed:

- **Renewability and use of sustainable management practices:** Renewable materials include wood, plant fibers, wool, and other resources that are potentially replaceable within a limited time period (such as a few decades or less) after harvesting. [26]

- **Resource quantity:** A fundamental strategy for resource-efficient building is to build less and use smaller quantities of materials in the construction process.

- **Local content and reduced transportation:** Specifying products made with local materials and labor can contribute to low embodied energy consumption and life-cycle cost for building materials.

- **Life-cycle cost and maintenance requirements:** Over the useful life of a commercial building, some materials will require maintenance and replacement more than once. When the full range of costs is considered, materials that are more costly upon initial purchase may be justified in terms of “avoided future costs.”

- **Regionally appropriate materials:** Some types of construction and materials are more appropriate in one region than another because of climatic differences.

[26] Council, P. T.-U. (1996). *Sustainable Building Technical Manual - Green Building Design, Construction, and Operations.* United States of America: Public Technology Inc. - US Green Building Council.

- **Reused materials:** Reusing does require extra effort, but the quality and cost savings of some reused materials can be considerable. The additional labor cost may be entirely or partly offset by savings on new materials, transportation, and dumping fees.

- **Resource recovery and recycling:** Once a material has completed its initial service in a building, it potentially has additional use as a resource and can later be recovered and recycled. The potential recyclability of metal, plastic, glass, wood and masonry are discussed below: [26]

  - Metals are recyclable if they can be separated by type. Accordingly, steel and aluminum building elements have a high recycling value.

  - Most plastics are recyclable, but the current rates of recycling are not high because the wide variety of plastics in use makes them difficult to separate. Additives, coatings, and colorants make recycling difficult.

  - Glass products can be recyclable if separated and uncontaminated.

  - Heavy timber is recyclable by salvaging or re-sawing. Engineered wood products, can be reused if they are fastened in such a way that they can be easily removed.

  - Concrete, clay, and other masonry products and ceramics are usually difficult to salvage and reuse. Some recycling of these products occurs by crushing them for use as granular fill.

- **Use materials in ways that ensure their durability:** It is still a general rule that by producing more durable products the use of raw materials is reduced. Lower quality materials should be used in such a way that they are easily replaceable, whilst more durable materials may be easily dismantled for re-use or recycling. The lifespan of materials is governed mainly by four factors: [13]

  - The physical structure and chemical composition of materials .
  - Maintenance and management.

  - The local environment, climatic and other chemical or physical conditions.

  - The construction and its execution, where and how the material is fitted into the building.

Conventional Material	Sustainable Alternative Material
Cement/ concrete	- Fly ash lightweight aerated concrete blocks. - Pre-cast hollow concrete blocks. - Pre-cast concrete blocks. - Precise aerated cellular concrete walling blocks and roofing slabs.
Metals	- Steel with verified recycled content. - Aluminium with verified recycled content. - Scrap/ salvaged steel & aluminium sections. - Antique iron and brass fixtures.
Masonry units	- Fly ash lime gypsum products (bricks, aerated concrete blocks, stabilized mud blocks). - Pre-cast materials (stone blocks, concrete blocks, hollow concrete blocks, cellular concrete units). - Stabilized compressed earth blocks.
Mortars & plasters	- Lime, pozzolanic materials, rice husk ash to replace part of cement in cement based mortars. - Fly ash (replacing 25% of cement).
Wood	- Medium density fibre boards. - Particle boards. - Rice husk boards. - Cement bounded composite panels.
Plastics	- Recycled plastic panels.
Glass	- Recycled content glass (fibre glass, glass wool). - High performance glazing.

Table 13 Examples of sustainable alternative materials **(Reardon & Downton)**

Table 13 shows some sustainable alternatives for main conventional materials. Cement, concrete and masonry units can be replaced with either lightweight or pre-cast alternatives. Metals, plastics and glass can be replaced with recyclable alternatives. Using Aluminum is less recommended due to its high-embodied energy and water. Fly ash can replace cement in mortars and plasters.

3.2.3.2. Aspects for materials used in Eco-resorts

The following are some main aspects for using materials:

- The surface of a trail should be resistant to continuous use. It is better to use natural permeable materials that allow water absorption by the ground and not surface flow; materials such as gravel, sand, wood shavings, small cross sections of tree trunks or branches, etc. Consider natural resin-based paving mixes instead of asphalt. [22]

- Make a comparative analysis of the advantages of using local materials vs. other materials, taking into account the following factors: economics, time, distance covered, environmental impact and socio-economic benefits to the local community on the long-term.

- New materials used should easily blend in with traditional materials, and should resist climatic extremes, such as humidity and temperature. Also, prefer light materials that are easy to transport and assemble on site.

- In the guest bathrooms:

    - Recently, most bathroom fixture companies have been turning their attention to some form of fiber glass or plastic tub and shower arrangements that can be delivered either in one piece or in several sections. This eliminates the necessity for the use of tile or other impervious wall material in this area.

    - The standard one-piece lavatory is fast disappearing from hotels. Instead, a lavatory is becoming a shelf arrangement into which the bowl is sunk. There are many companies manufacturing synthetic marble that make the bowl and the ledge in one piece.

- In the kitchen:

    - The floor should be of some material which can be easily cleaned. In the past, the better kitchens used ceramic tile. There are many new types of floor preparations which can be applied directly over the concrete slab and which lend themselves to easy cleaning and offering a firm foothold.

    - The walls were usually ceramic tile. Here again, the new plastic materials are by some standards even better than tile, with its cement. To hold down the noise level in the kitchen, it is preferred to use a perforated metal ceiling with acoustic botts above or a ceramic-treated acoustical material.

3.2.3.3. Water-consuming materials

Table 14 shows the main building materials categories and their environmental characteristics:

Materials		Density [kg/m^3]	Energy [MJ/kg]	Water [l/kg]
Bricks and tiles	Ordinary brick	1,800	3.562	1.890
	Light clay brick	1,020	6.265	1.415
	Sand-lime brick	1,530	2.182	3.009
	Ceramic tile	2,000	15.649	14.453
	Quarry tile	2,100	2.200	3.009
	Ceramic roof tile	2,000	4.590	2.456
	Concrete roof tile	2,380	2.659	4.104
	Fibre cement roof slate	1,800	11.543	20.368
Insulation materials	EPS foam slab	30	105.486	192.729
	Rock wool	60	26.393	32.384
	Polyurethane rigid foam	30	103.782	350.982
	Cork slab	150	51.517	30.337
	Cellulose fibre	50	10.487	20.789
	Wood wool	180	20.267	2.763
Cement / Concrete	Cement	3,150	4.235	3.937
	Cement mortar	1,525	2.171	3.329
	Reinforced concrete	2,546	1.802	2.768
	Concrete	2,380	1.105	2.045
Wood products	Sawn timber, softwood, planed, kiln dried	600	20.996	5.119
	Sawn timber, softwood, planed, air dried	600	18.395	4.192
	Glued laminated timber, indoor use	600	27.309	8.366
	Particle board, indoor use	600	34.646	8.788
	Oriented strand board	600	36.333	24.761
Common materials	Reinforcing steel	7,900	24.336	26.149
	Aluminium	2,700	136.803	214.341
	Polyvinylchloride	1,400	73.207	511.999
	Flat glass	2,500	15.511	16.537
	Copper	8,920	35.586	77.794

Table 14 Environmental characteristics of building materials
(Bribián, Capilla, & Usón, 2010)

The water consumption Figure 32, based on data in the table above, shows that Petro-chemical based materials have the highest water consumption. Metals come in the second place. Glass, fiber and wood based materials are located in the intermediate ranks. Cement (concrete) and earth based materials (bricks and tiles) are the lowest water-consumers.

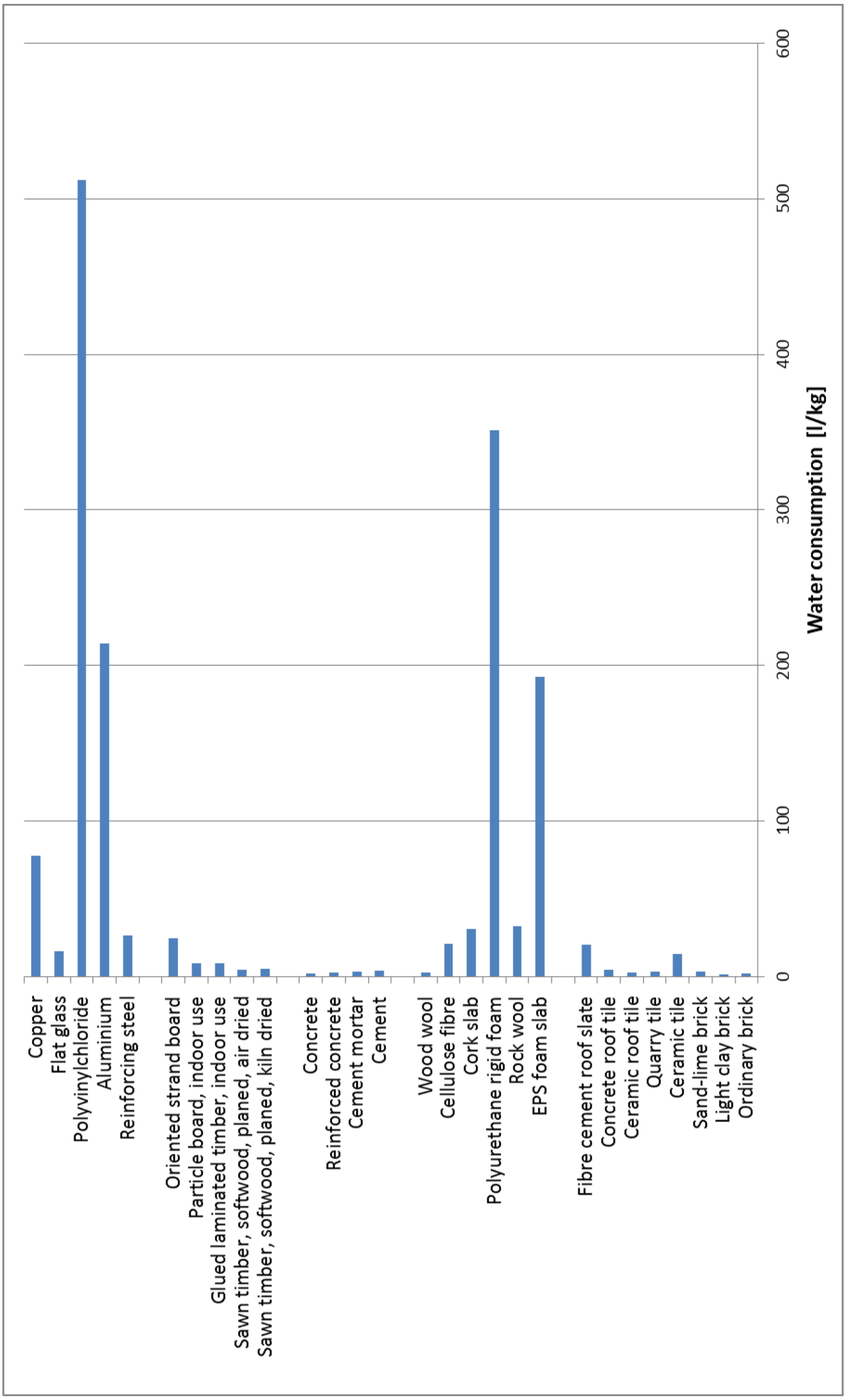


Figure 32 Water-Consuming materials chart, data from **(Bribián, Capilla, & Usón, 2010)**, graphed by researcher

Chapter conclusions

From this chapter, conclusions can be summarized as followed:

1. According to international Eco-tourism associations, eco-resorts should cause minimal or no damage to the local environment and communities.

2. In resorts, water should be conserved during the whole project life cycle including design, construction and operation phases.

3. Designing eco-resorts in such regions should be highly water-efficient. Main outputs that can be achieved by applying water-efficient guidelines for designing eco-resorts include:

   - Conserving natural water sources and ecosystems / considering sewage disposal.
   - Benefiting from rainy seasons and excessive humidity / Defining dry seasons / Locating disposition patterns.
   - Studying soil permeability, rechargeability and water absorption / benefiting from available potable and non-potable water sources / Defining water quality.

   - Benefiting from native vegetation and plants having high drought tolerance and low water consumption / Reducing coastal groundwater salinity using salt-tolerant plants.
   - Using traditional and local water-efficient design practices / Respecting cultural aspects and social habits concerning water conservation.

   - Increasing ground recharge and natural irrigation / reducing runoffs.
   - Using natural water bonds and lakes as swimming pools.
   - Minimizing leakage by lowering traveling distance for water networks / Achieving optimum water saving by arranging functional zones efficiently.
   - Conserving water using water-rated fixtures and techniques.

4. In construction practices, structural systems and building materials used in such arid and semi-arid regions should have high water-efficiency.

5. Cement, concrete, quarry tiles and bricks, such as sand-lime and light clay bricks, are proved to be the lowest water-consumers compared with other widely-used building materials like Steel, Aluminum and Polyvinylchloride.

Chapter four: Water efficient usage in resorts during operation phase

4.1. Potable water usage
4.2. Non-Potable water usage

Guiding definitions

	Term	Definition
Reused water classification	Blue water	Water quality suitable for potable use from springs and wells, from high-quality surface water bodies, unpolluted rainwater, and water treated to potable water quality
	White water	Mildly polluted surface runoff
	Gray water	Medium polluted water from laundries, bathrooms (shower and bathtub), washing, emulsifie with soaps and detergent; may have significant concentrations of biodegradable and nonbiodegradable organics, and may also contain pathogens
	Black water	Highly polluted wastewater from toilets and urinals, containing urine and excreta and drain water from kitchen sinks with disposal units
	Yellow water	Separated urine (about 1% of the total flow)
	Brown water	Black water after yellow water is separated
	Green water	Water use in irrigation
Processing	Water reuse	Use of the used water effluent for the same or another beneficial use, with treatment before the reuse
	Water treatment	Capture, reclaming, or processing of used water or stormwater to make it reusable
	Water recycling	Repeated recovery of used water from a specific use, and redirection of the water either back to the original or to another use
Product	Treated wastewater	The end product of used water reclamation that meets water quality requirements for biodegradable materials, suspended matter, and pathogens for the intended reuse
	Direct reuse	The direct use of treated wastewater for applications such as agricultural and urban landscape irrigation, cooling water and other industrial uses, urban applications for washing streets or firefighting and flushing toilets
	Indirect reuse	Mixing, dilution, and dispersion of treated wastewater by discharge into an impoundment, receiving water, or aquifer prior to reuse, such as groundwater recharge with a significant lag time between the use and reuse
	Potable water reuse	Use of highly treated used water to augment drinking water supplies
	Non-potable reuse	Includes all water reuse applications other than direct or indirect use for drinking water supply

Table 15 Definitions of water reuse **(Novotny, Ahern, & Brown, 2010)**

Most futurists agree that water will become the most important resource in this century, even more than land. Because of the remote nature of most eco-resorts, water is often a precious resource. Water is scarce in many parts of the world, and it is important that an eco-resort enhances the ecological and educational experience of your guests by demonstrating world-class water conservation and management.

Many resorts around the world experience problems with water supply. The lack of potable and non-potable water has been a major constraint for coastal resorts as well as those in semi-arid and arid regions. The architect should seek alternative, sustainable means of acquiring water for the eco-resort, as well as means of reducing consumption.

At all times, however, the quality of water for consumption is of paramount importance, as is the intelligent re-use of graywater. Resorts only use about 10% to 15% of processed water for drinking and cooling, and it is plainly extravagant to use it for flushing the toilet, bathing and showering, and watering the resort gardens. [22]

4.1. Potable water usage

Potable water is used for many functions that do not require high-quality water such as toilet and urinal flushing, and landscape irrigation. Using large volumes of potable water increases maintenance and lifecycle costs for building operations and increases consumer costs for additional municipal supply and treatment facilities.

Conversely, facilities that use water efficiently can reduce costs through lower water use fees, lower sewage volumes, and lower capacity charges and limits. Many water conservation strategies involve either no additional cost or rapid paybacks. Effective methods to reduce potable water use include:

4.1.1. Sanitary fixtures

Sanitary fixtures in public buildings include:

4.1.1.1. Taps

Typical taps discharge 15 to 18 L/min compared with low-flow and aerating models which use as little as 2 L/min depending on the intended application and taps with an aerator or flow restrictor may reduce flow to less than a third of standard taps. [27]

Water-efficient taps can be used following the guidelines below:

- Fixing leaks immediately, a tap leaking at the rate of one drip per second will waste more than 12,000 liters of water a year. [27]

- Installing mixer taps in showers. They can save large amounts of water wasted while trying to get a comfortable water temperature.

4.1.1.1.1. Control systems

Many water control systems are available for commercial taps. Automatic shutoff – such as push-button or lever-operated taps that shut off automatically after a set time (e.g. a 6-star rated tap has a running time set between 5 to 10 seconds at a flow rate of 4 L/sec). [28]

Figure 33 an infrared sensor tap
(Reardon & Downton, 7.1 Water Use)

4.1.1.2. Showers

A standard showerhead uses about 15 to 25 liters of water per minute - a three star rated water efficient showerhead uses as little as 6 or 7 L/min. [27]

Sensor-operated and automatic shut-off taps can be installed in showers, particularly for high-usage washrooms.

Figure 34 innovative shower
(Reardon & Downton, 7.1 Water Use)

[27] Reardon, C., & Downton, P. (n.d.). *7.1 Water Use.* Retrieved February 11, 2012, from Technical Manual - Design for lifestyle and the future: http://www.yourhome.gov.au/technical/fs71.html

[28] Corr, K., Adams, I., & Boynton, D. (2009, May 30). *Water use and sustainable commercial buildings*. Retrieved October 26, 2010, from Your building - Prospering from Sustainability: http://www.yourbuilding.org/Article/NewsDetail.aspx?p=83&id=1584

The use of low-flow showerheads can save approximately 27 liters/day/ person (for a person who mainly showers rather than takes baths). The cheaper alternative to low-flow showerheads is to fit a flow restrictor to the supply to an existing showerhead, although this may increase the showering time. [29]

4.1.1.3. Toilets

4.1.1.3.1. Gravity Flush toilets

Water-efficient toilets can be used following the guidelines below:

- Fixing leaking toilets, a slow leak can waste more than 4,000 liters per year. Visible, constant leaks can waste more than 96,000 liters. [27]
- Displacement devices, including bags or bottles, can reduce water flow by approximately 2.84 L/flush. They function by displacing flush water stored in the tank. The devices are inexpensive and easy to install, but do require regular maintenance. [30]
- Toilet dams are flexible inserts placed in a toilet tank to keep 1.9 to 3.78 liters out of each flush cycle. Dams will last five to six years. [30]
- Early closure flapper valves replace the existing flush valve in the tank. These devices are adjustable to optimize performance and can save 1.9 to 7.57 L/flush. Early closing flappers are inexpensive and usually can be installed in 10 to 15 minutes, barring other problems with the toilet's mechanisms. [30]

4.1.1.3.2. Flush valve (Flushometer) toilets

Flush valve, or flushometer, toilets use water line pressure to flush waste into the sanitary sewer system. They consist of a valve and a toilet bowl fixture. Most commercial/industrial facilities use flush valve toilets, especially in higher-use areas.[30] These toilets can work efficiently using the guidelines below:

[29] Roaf, S., Fuentes, M., & Thomas, S. (2001). *Ecohouse: A Design Guide.* Oxford: Architectural Press.

[30] *Water Efficiency Manual - for Commercial, Industrial and Institutional Facilities.* (2009). North Carolina: A joint publication of the Division of Pollution Prevention and Environmental Assistance and Division of Water Resources of the N.C. Department of Environment and Natural Resources, and Land-of-Sky Regional Council.

- Replacing the existing valve of a 18.9 L/flush unit with a 13.25 L/flush valve without changing the toilet bowl fixture. This valve inserts are available that can reduce flush volumes by 1.9 to 3.78 L/flush. [30]

- An economical water-saving opportunity exists to retrofit 6 L/flush valve toilets with a dual flush valve. The valve is actuated upwards to flush liquid waste and downward to flush solids. [30]

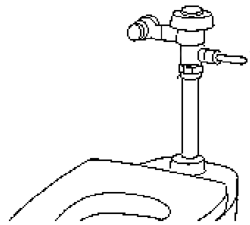


Figure 35 a Flush Valve (Flushometer) toilet **(Reardon & Downton, 7.1 Water**

4.1.1.3.3. Dual flush toilets

Water can be saved when replacing existing single-flush toilets (use up to 13 liters of water per flush) with dual-flush toilets. The most common dual-flush toilet is the 6-liter full flush/3-liter half flush, although a 4.5/3 L dual-flush toilet is now available. An electronic sensor-activated dual-flush unit activates the appropriate flush, depending on the length of time the user remains seated. [28]

4.1.1.3.4. Pressurized tanks system toilets

Using water line pressure to compress air in a specially sealed tank in the toilet, when the water is released into the bowl it has a much greater velocity than from a conventional toilet. Another type of water and compressed air toilet uses water to rinse the bowl and compressed air to evacuate the contents. [29]

4.1.1.3.5. Composting toilets

Composting toilet systems may utilize self-contained (local) toilets or centralized units with a “destination” catchment area. Self-contained units utilize small pans or trays to remove the humus.

Centralized systems are available in both batch and continuous systems. Both systems need only infrequent attention, often once or twice per year. Some regular maintenance will be necessary with any composting toilet system.

Composting toilets can be used following the guidelines below:

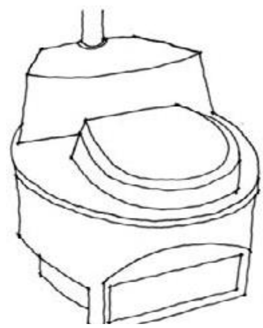


Figure 36 Self-contained composting toilet **(Kwok & Grondzik, 2007)**

- Ventilation of catchment spaces, as well as direct system ventilation, is necessary. Ventilation systems should exhaust a minimum of 0.6 m above the building roof peak. [31]

- Water closets must be placed vertically above a catchment tank to permit proper transport of solid waste materials. Pipes or chutes that connect fixtures to tanks generally have a diameter of 355 mm. A maximum of two water closets per catchment tank is generally advised. [31]

- Catchment tanks require a minimum of 0.3 m of overhead clearance for pipe connections and 1.2 m of clearance in front of tanks for removal of composted material. Direct access to the exterior of the building from the catchment tank area is suggested. The catchment tank area should be properly drained and free of flood risk. [31]

- Sizing of composting toilet units or systems is dependent upon building occupancy and anticipated usage. Table 16 provides a sense of the dimensions of common equipment. Multiple tanks are common in higher-use (commercial/institutional) situations. Composting toilet units are similar in footprint to conventional water closets.

Type	USES/DAY	LENGTH (cm)	WIDTH (cm)	HEIGHT (cm)
Self-contained	6	64	84	64
Remote tank	9	112	66	68
Remote tank	12	175	66	76
Remote tank	80	292	158	162
Remote tank	100	292	158	226

Dimensions for remote tank units include the catchment tank, but not the toilet (which is a separate component).

Table 16 Typical composting toilet dimensions **(Kwok & Grondzik, 2007)**

Composting toilet design procedures are discussed in Appendix A.

[31] Kwok, A. G., & Grondzik, W. T. (2007). *The Green Studio Handbook - Environmental strategies for schematic design.* Oxford: Elsevier Inc.

E. Batch composting toilets

Batch CTs consist of two or more containers that are alternated so that the active container is being used while the pile in the fallow container has time to compost without the addition of fresh excrement and the potential for re-contamination.

An example of an owner-built batch CT is the 'wheelie-batch' where containers are alternated underneath the toilet seat. The Fixed Chamber Batch is another example of a batch CT where the two containers are permanently in place and the seat is moved when the time comes to change containers. [27]

F. Continuous composting toilets

Although the major problem with this type of toilet is its size, about twice the size of a conventional toilet suite or more, they have several advantages:

- No water is used.
- A small amount of energy is needed for an exhaust fan.
- Valuable nutrients can benefit soils.
- Proper maintenance requires little time.

Large (greater than 15 m^3) composting toilets do not usually require the external input of energy for the process, as the aerobic decomposition is sufficiently exothermic to be self-sustaining. Large composting toilets may be environmentally acceptable as they consume only a small volume of water, require no drainage pipe work and produce compost that can be used in the garden. [29]

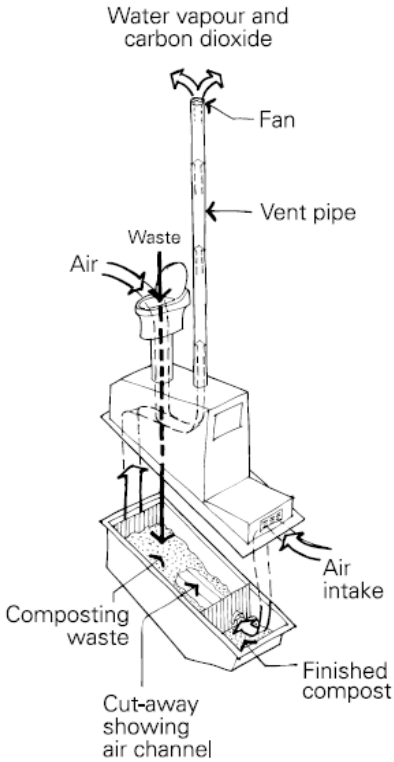


Figure 37 a continuous composting toilet **(Reardon & Downton, 7.1 Water Use)**

4.1.1.3.6. Vacuum toilets

Vacuum toilets remove waste from the toilet bowl using a vacuum pump. The waste is macerated and either discharged to the sewer or transported to a holding tank or treatment system. These are commonly used in aircraft and marine transportation, and are increasingly being used in commercial and public restrooms. The average amount of water used is between 1 and 1.5 L/flush. [28]

4.1.1.3.7. Incinerating toilets

Incinerating toilets are designed to handle only the black water component of the waste stream. Although black water contaminants are totally eliminated from the waste stream, a septic system must still be installed to treat the graywater generated.


Figure 38 an Incinerating toilet image / section **(Roaf, Fuentes, & Thomas, 2001)**

4.1.1.4. Urinals

4.1.1.4.1. Low water use urinals

Water is applied automatically through a continual drip-feeding system or by automated flushing at a set frequency, regardless of whether or not the urinal has been used. Water consumption varies with the system model, settings and usage rate, from 50 to 100 kL/year (30 to 70 flushes of 4 liters each per day). Cyclic 'fill and dump' units operating on 24 hours a day, 7 days a week basis can waste over 500 L/year. [28]

Urinals that use lower amounts of water include:

- Sensor operated - these detect the presence of people through movement sensors or door switches (combined with an electronic delay to stop flushing for a set period after flushing).
- Single unit systems - these replace trough and gutter systems with single unit systems that have individual flushes.

Standard trough-type urinals use an average of 6 liters of water per flush, while water-efficient urinals use 2.8 L/flush. Developments have resulted in Smart Flush systems using 0.8 L/flush. [28]

4.1.1.4.2. Waterless urinals

Waterless urinals are being used in commercial buildings, hotels and government institutions. Most of these urinals operate through the use of an oil barrier between the urine and the atmosphere, preventing odours from escaping. The potential water savings from a waterless urinal is approximately 1.5 ML/year, based on typical usage of four flushes per day. [28]

Waterless systems are more economical to purchase and install than flush urinals because they have no flushing mechanism. Waterless urinals offer the savings of flush water and sewer charges, but their costly cartridges for the drain are typically replaced every 7,000 uses. [30]

Figure 39 a waterless urinal section **(Corr, Adams, & Boynton, 2009)**

4.1.2. Water flow controllers

4.1.2.1. Aerators

Aerators are used as tap flow controllers for existing taps. Aerators screw onto the tap head and add air to the water flow while reducing water flow. They are available at common ratings of 1.9, 2.84 and 3.78 L/min. Flow rates as low as 1.9 are adequate for hand wetting purposes in a bathroom setting. Higher flow rate kitchen aerators deliver water at 7.57 to 9.5 L/min for more general washing purposes. [30]

4.1.2.2. Flow restrictors

Flow restrictors are readily available and can be fitted to many appliances, but their use has to be appropriate. Where taps can be left open by careless users and where items are washed under running water. However, a more effective but more expensive solution would be to install taps operated by proximity sensors.

Common flow rate designs include 1.9, 2.84, 3.78 and 5.68 L/min. Flow restrictors can be used where aerators cannot be used or where there is tap abuse (aerator removal is problematic). [30]

4.1.2.3. Control sensors

"Electric eye" sensors are available for a number of plumbing applications, including lavatory taps, urinals and toilets. These devices deliver a metered flow only when the fixture is in use. For taps, both the flow rate and activation time can be adjusted. The "no-touch" activation also is helpful to prevent the spread of disease and useful for users with disabilities.

Automatic leak detectors are becoming increasingly available. These devices are fitted into the incoming mains and close when a leak is detected, preventing both the waste of water and damage to property. Some operate by sensing a high flow rate and others use conductivity detectors to activate valves. Automatic closure taps can produce water savings in commercial and public buildings where there is a risk of taps being left open accidentally.

4.1.2.3.1. Urinal flushing cistern controllers

The average urinal uses about 2.2 L/flush compared with the most efficient urinals which use 1.5 L/flush, a reduction of more than 30 per cent. An increasing number of urinals have 'smart controls' to reduce unnecessary flushing and the most efficient urinals combined with smart controls reduce water use by 40-50 per cent. [27]

There are various methods of sensing use and operation. Some use changes in water pressure to identify operation of urinals; others use passive infrared (PIR) detectors to detect movement of persons in the room; some sense the temperature of urine in the urinal traps; and many use various forms of proximity detector.

4.1.3. Kitchen

Inefficient uses of water in kitchen operations come mainly from two areas: equipment design and behavioral patterns. The main types of water-using equipment found in kitchens are dishwashers, taps, ice-making machines and garbage disposals.

4.1.3.1. Dishwashers

Water usage across commercial dishwasher classes does not appear to be directly related to the size of the machine and varies from 1.25 L/rack to 75.7+ L/rack. A typical commercial dishwasher uses approximately 15.14 L/rack. Using an appropriately sized, water efficient model will save a significant amount of water. [30]

Commercial dishwashers, considered to be one of the largest water and energy consumers in a food service area, often use more than two-thirds of the overall kitchen water use. There are four main classes of commercial dishwashers: undercounter, stationary rack door type, rack conveyor and flight type. [30]

Each class of dishwasher may employ single or multiple wash tanks, and use hot water (high-temp machines) or chemicals (low-temp machines) to achieve final rinse dish sanitization.

Figure 40 a dishwashing machine **(Reardon & Downton, 7.1 Water Use)**

4.1.3.1.1. Water efficient guidelines for dishwashers

The volume of consumption in dishwashers can be reduced by:

- Reuse rinse water to pre-rinse or wash dishes.
- Install advanced rinse nozzles.
- Check volumes of service and estimate facility needs. A better option may be a larger machine that has a lower water flow per rack rate.
- Install door switches for convenient on/off access.
- Use “steam doors” to prevent loss of water due to evaporation.
- Install “electric eye sensors” to allow water flow only when dishes are present.

Table 17 shows that stationary rack-door dishwashers are suitable for small kitchens and its rinse water can be recyclable. The rack conveyor dishwashers are used for medium sized kitchens with the ability to recycle final rinse water and be automatically operated using a sensor. The flight dishwashers are the best for large kitchens sharing the water-saving techniques applied to rack conveyor dishwashers in addition to its ability to use built-in booster heaters for more water savings.

Stationary Rack Door	Rack Conveyor	Flight
Stationary rack door mach-ines are the most widely used for commercial dishwashing machines.	Or C-line, machines use a motor-driven conveyor belt to move the rackloaded dishes through a large tank with separate wash and rinse compart-ments. Most widely-used in hotels.	Flight-type dishwashers provide high volume washing capability needed only in the largest commercial facilities.
Designed to service 50-200 people	Suited for service of 200 or more people.	The largest dishwasher
These box-shaped machines have one or multiple doors that slide vertically for load-ing and unloading. Stationary rack door type machines are available in both hot water machines are (the most water efficient) and chemical	Rack conveyors come in varying sizes, with available additions such as pre-wash units, sideloading trays, cond-ensers and blowerdryers. A single tank holds the water and detergent at a regulated temperature.	Similar in that they use a conveyor belt to move dishware, flight-type mach-ines do not have racks. Rather, dishes are loaded directly onto the belt.
Some stationary rack door machines have the ability to recycle rinse water to be used again in a wash cycle.	Recycled water from the final rinse is usually used. Installation of an electric eye sensor (that keeps the conveyor from running when there are no dishes on the racks) make conveyors more water-, energy- and cost-effective.	The recirculation of final rinse water, electric eye sensors, extra-wide conveyors and low-energy built-in booster heaters can translate to water savings as much as 47 percent, while maintaining loads of more than 14,000 dishes per hour.

Table 17 Comparison between medium and large dishwashers **(Resources, 2009)**

4.1.3.2. Kitchen taps

Taps can waste large amounts of water, as they are the most heavily used water source in kitchens. Conventional taps have typical flow rates of 9.46 to 15.14 L/min. By simply installing a brass gasket and an automatic shut-off nozzle, a facility could save as much as 79500 liters of water per year. Taps used in kitchens will be either the conventional type or pre-rinse pressure sprayers. [30]

4.1.3.2.1. Water efficient guidelines for kitchen taps

The volume of consumption can be reduced by:

- Install a flow restrictor to limit maximum flow rate to 9.46 L/min or less. [30]

- Adjust flow valve to reduce water flow.
- Install a 8.33 L/min tap aerator, maximizing flow efficiency by increasing airflow to the stream. [30]

- Consider infrared or ultrasonic sensors that activate water flow only in the presence of hands or some other object.
- Install pedal operated tap controllers to ensure valves are closed when not in use.

4.1.3.2.2. Pre-Rinse Sprayers

Known as high-efficiency sprayers, these inexpensive nozzles use less water and can also cut the water bill. They are used to remove leftover grease and food off dishes, pots and pans before they go into a dishwasher.

While conventional sprayers use between 9.46 and 15.14 liters of water per minute, the high-efficiency sprayers use from 6 to 10 L/min. The new generation of sprayers also comes with an automatic shut-off valve at the hose head, so water is supplied only when needed. [30]

4.1.3.3. Ice Machines

Ice machines have many commercial uses and can use large amounts of water, depending on the type of machine and the desired type of ice. Ice machines are composed of the following components: a condensing unit used for cooling, an evaporator surface for ice formation, an ice catcher, an ice storage container, and in some models, a dispenser. [30]

The type of condenser an ice machine uses will have the largest effect on water use. Two types of condensers are available: air-cooled and water-cooled. Water-cooled machines use 10 times as much water as air-cooled machines and water rarely is re-circulated. [30]

4.1.3.4. Garbage Disposals

Studies show that garbage disposals can waste a large amount of water. It is recommended that their use be minimized or eliminated from kitchen operations. Many facilities use strainers or traps that employ a mesh screen to collect food waste for proper waste treatment. Another option is to install strainers in sinks, leaving the food matter in the sink for disposal in trash receptacles or composting units.

4.1.4. Laundry

4.1.4.1. Clothes washing machines

Large amounts of water are regularly used in laundering facilities for operations that include the wash and rinse cycles of washing machines, steam-heated dryers, steam-pressing equipment and reclamation of dry solvent. Washer-extractors and most other traditional large-scale washing machines use fresh water for each wash and rinse cycle.

Modern high efficiency clothes washing machines use far less water than conventional machines. A water efficient washing machine uses 68 liters of water for a 5 kg fill. This is around one-third of the water used in a conventional machine. [29]

Figure 41 a washing machine **(Reardon & Downton, 7.1 Water Use)**

By 2016 clothes washer could save about 25,600 mega liters of water per year-enough to fill 12,500 Olympic swimming pools every 12 months (this is a reduction of about 8.8 per cent in the water consumption of the clothes washers sold between 2003 and 2016).[27] Water efficient guidelines for clothes washing machines include:

- Reduce water levels, if possible, for partial loads.
- Avoid excessive back-flushing of filters or softeners; back-flush only when necessary.
- Replace traditional commercial clothes washers (vertical axis) with high efficiency washers (horizontal axis), which can save as much as two thirds of the energy and water used by traditional models.
- Install a computer-controlled wash and rinse water treatment and reclamation system. By recycling both wash and rinse water and diverting rinse water to a storage tank for later reuse as wash water, these systems can reduce a laundry's water demand by about 50 percent. [27]
- Install a continuous-batch (or tunnel) washer, which can reduce water demand by about 70 percent compared with that of washer-extractors. [27]
- Install an electrically generated ozone laundry system, which can reduce water use by about 10 percent compared with that of traditional laundering systems. The ozone acts as a cleaning agent and also reduces detergent use by 30 to 90 percent. [27]

4.1.5. Boilers

As clean steam is released from the boiler, impurities build up. The increasing concentration of suspended solids impurities in the boiler can form sludge, which impairs boiler efficiency and heat transfer capability. Too much blowdown can lead to wasted water, treatment chemicals and energy. The optimum amount of blowdown required is a function of boiler type, steam pressure, chemical treatment program and feed-water quality.

4.1.5.1. Blowdown controls

There are two types of boiler blowdown: manual and automatic. Plants using manual blowdown cannot immediately respond to the changes in feedwater conditions or variations in steam demand. An automatic blowdown control can keep the blowdown rate uniformly close to the maximum allowable dissolved solids level, while reducing blowdown and energy losses. Changing from manual blowdown control to automatic control can reduce blowdown water losses by up to 20 percent. [30]

4.1.5.2. Maximizing condensate return

Improving condensate return is another way to minimize blowdown water and maximize cycles of concentration. By increasing condensate return, operators will increase the concentration cycles, decrease blowdown and conserve the heat value of the high-temperature condensate. When steam traps exceed condensate temperature, the trap is leaking steam.

4.1.6. Air-conditioning

To cool indoor air for buildings, air conditioning equipment needs a coolant. The coolant can be either water or refrigerants. In water-cooled air conditioning systems, a water chiller is used to chill the coolant water. Water chillers are air-cooled or water-cooled in releasing heat from the heat exchanger. For a single building, air-cooled chillers are used most commonly. For larger buildings, water-cooled chillers are used.

4.1.6.1. Cooling towers

In a water-cooled chiller system, circulating cooling water can be cooled directly with a cooling tower (open-circuit type), or a separate cooling tower water can be used indirectly for cooling (closed-circuit type). Water is lost from cooling towers through evaporation, bleed, drift, splash and overflow. Where installed, cooling towers can account for up to 30% of the total water used in an average building; a statistic that is even higher in summer. [28]

	Definition
Evaporation	Water vapor carring away the heat resulted from cooling water drips using fans which pull or push air through the tower in a counterflow, crossflow or parallel flow to the falling water drips in the cooling tower.
Blowdown	Blowdown is a term for water that is removed from the recirculating cooling water to reduce contaminant buildup in the tower water. As evaporation occurs, water contaminants, such as dissolved solids, build up in the water.
Drift Losses	Drift is a loss of water from the cooling tower in the form of mist carried out of the tower by an air draft. A typical rate of drift is 0.05 to 0.2 percent of the total circulation rate.

Table 18 definition of water outputs in cooling towers **(Resources, 2009)**

4.1.6.1.1. Make-up water (regular water input)

Make-up water is water added to the cooling towers to replace evaporation, blowdown and drift losses. The amount of make-up water added directly affects the quality of water in the system. [30]

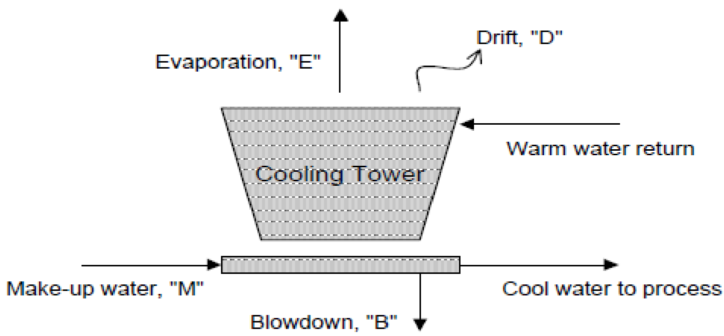


Figure 42 a schematic showing water balance in cooling towers **(Resources, 2009)**

4.1.6.1.2. Water-efficient improvements for existing system

- To reduce uncontrolled water losses:
  - Install drift eliminators.

  – Install anti-splash louvers or splash mats.
- To reduce controlled water losses:
  – Automatic bleeds to occur when the conductivity is too high.
  – Increase the cycle of concentration (ratio of concentration of dissolved solids in condenser water to that of the make-up water), as shown in Table 19.

Initial Concentration Ratio	New Concentration Ratio										
	2	2.5	3	3.5	4	5	6	7	8	9	10
1.5	33%	44%	50%	53%	56%	58%	60%	61%	62%	63%	64%
2	--	17%	25%	30%	33%	38%	40%	42%	43%	44%	45%
2.5	--	--	10%	16%	20%	25%	28%	30%	31%	33%	34%
3	--	--	--	7%	11%	17%	20%	22%	24%	25%	26%
3.5	--	--	--	--	5%	11%	14%	17%	18%	20%	21%
4	--	--	--	--	--	6%	10%	13%	14%	16%	17%
5	--	--	--	--	--	--	4%	7%	9%	10%	11%
6	--	--	--	--	--	--	--	3%	5%	6%	7%

Table 19 Make-up water saved after increasing concentration ratio **(Resources, 2009)**

- To reduce potable Make-up water:
  – Catch air handler condensation and route it to the tower, be sure to check for bio compatibility.
  – Catch rinse waters from processes such as softeners, demineralizers, etc. and route as tower make-up.
  – Catch rain water, filter and test appropriately to feed tower.
  – Consider advance recycle techniques such as ultrafiltration.
  – Consider other water reuse sources and quality, such as centrifuge blowdown.
  – Ensure the tower is set up to minimize or eliminate overflow during intermittent operation when headers may drain to the sump.
- Use of bypass valves to enable condenser water from chiller to by-pass the cooling tower and return directly to the chiller, thus reducing losses.
- Capture bleed-off in a backwash holding tank and use to backwash side stream filters, monitor use by sub-metering and regular maintenance.

4.1.6.1.3. Alternative heat-rejection systems

Alternative heat-rejection systems include: [28]

- Air-cooled chillers (although these take up more floor space than water-cooled chillers).
- Water source geothermal systems, which directly or indirectly use underground storage aquifers.

- Liquid coolers (dry and evaporative).
- Variable volume refrigerant systems.
- Refrigerant air-conditioners.
- Adsorption chillers, powered by natural gas.
- Ice storage and chilled water storage systems.

- Ground source geothermal systems, where cooling water is passed through long loops buried underground.
- Sea or lake water cooling.
- Hybrid systems.
- Night sky cooling.

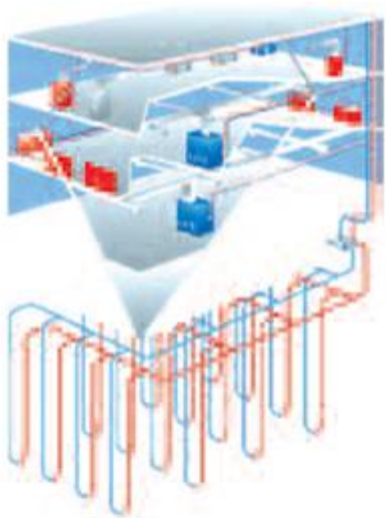


Figure 43 Left: Air-cooled chiller, Right: Schematic of ground source geothermal system **(Corr, Adams, & Boynton, 2009)**

4.1.6.2. Evaporative cooling

Evaporative coolers cool air through moisture evaporation. Systems range from small portable units that must be manually filled with water, up to very large ducted systems, which are the most common in businesses. The evaporative cooling systems are more suited to dry, hot climates and less suited to humid climates. Evaporative air-conditioners consume a large amount of water in two ways:

- The evaporation of water from the pads which cools the air.
- The dumping/bleeding-off of water to reduce the mineral concentration in the sump.

4.1.6.2.1. Water-efficient improvements for existing system

There is little opportunity for reducing water consumption through evaporation of water to cool the air without loss of function and efficiency. Opportunities to reduce this water loss are mainly through alternative operation methods, such as:

- Replacing evaporative cooling systems with refrigerative systems.
- Not bleeding off any water from the evaporative air-conditioner. However, this option requires more frequent servicing and cleaning.
- Treating the water being supplied to the evaporative air-conditioner to reduce scaling. This option involves an additional cost and regular servicing, but involves easier cleaning and the pads last longer.
- Switching to automatic sump dump systems, where water is automatically dumped when salt content becomes excessive. This option uses much less water than bleed-off systems.
- Reducing the size of the sump so that a smaller amount of water is dumped each time.
- Exploring the viability and water use of two-stage coolers, which use an air-to-water heat exchanger to reduce the incoming air temperature without raising humidity before passing the air through a direct evaporation stage to further cool the air.

4.1.6.3. Air-cooled refrigerative systems

Air-cooled refrigerative air-conditioning systems do not use any water; however, they are relatively energy intensive. Once a certain capacity of system is reached, it is less cost-effective to use air-cooled systems in a commercial building, and other types of system configurations need to be considered. The air-conditioning process consumes water in two ways:

- Condensate is produced, which is a potential alternative water supply.
- The embodied water of power generation; Coal power stations may use as much as two to five liters of water per kilowatt hour of power produced, representing a large proportion of the water used by air-conditioning over its life cycle.

4.1.6.4. In-ground heat source pump (IGHSP) cooling system

A recent development in cooling system technology is the use of in-ground heat source pump (IGHSP) cooling systems: the IGHSP cooling system utilizes the earth below the ground surface as the heat source and sink. As a result, the water consumption is significantly reduced without the usual decrease in energy efficiency that can result from air-cooling systems.

Although the initial cost of installing the system is higher than the water-based cooling system, the operating cost in relation to water and energy use, is significantly lower. The hydro-geological features of the site are important in determining the feasibility of the system.

4.1.7. Swimming areas and recreational waterscape

Swimming pools and recreational waterscape are serious consumers of water and should be made as sustainable as possible in terms of treatment and filtration. Carefully investigate and recommend water treatment systems that offer the least impact for water hardness and other circumstances.

4.1.7.1. Swimming alternatives

The selection of an alternative for swimming depends on the purpose of the project, the necessary size of the water body, and the particular amenities of the site. The alternatives can be categorized as followed:

- Design swimming pools only in sites where water supply is sufficient, perhaps where catchment or solar distillation is an option.

- For small swimming areas, filtered, chemically treated swimming pools are usually the most appropriate, and they can be built almost anywhere. For larger facilities, ponds or lakes are likely to be the most appropriate, but their feasibility is a function of hydrologic, geologic, and topographic opportunities. [32]

[32] Harris, C. W., Dines, N. T., & Brown, K. D. (1998). *TIME-SAVER STANDARDS FOR LANDSCAPE ARCHITECTURE: DESIGN AND CONSTRUCTION DATA - 2nd Edition.* New York: McGraw-Hill, Inc .

4.1.7.2. Water efficiency

The main considerations for the water efficiency needed in swimming areas and recreational waterscape are:

- Ensure that the water treatment and filtration is the most effective available to minimize water.
- Consider shading some pool areas to reduce evaporation.
- Securely cover a pool when it is not in use. Aside from the safety benefits, a cover that excludes light will effectively turn a pool into a tank, preventing algae growth, and reducing maintenance of the water to a bare minimum.

4.1.8. Landscape

In areas with low rainfall or seasonal droughts, up to 60 percent of total seasonal water usage can be attributed to irrigation.[26] Typical urban landscapes consist of non-native or unadapted plant species, lawns, and a few trees. Non-native plants increase demands for water, especially during the growing season. Native plants have become adapted to natural conditions of an area such as seasonal drought, pest problems, and native soils.

The main aspects of potable water usage in Landscape are discussed as followed:

- Avoid using potable water for irrigating. Use filtered water from backwashing and draining the pool to irrigate gardens.
- Minimizing paving of outdoor areas as paved areas increases water run-off from the site.
- Planting trees to create natural shade and windbreaks to reduce evaporation. High water-use plants are best located in areas where they are sheltered from drying winds and strong sunlight.

Figure 44 Outdoor paving **(Reardon & Downton, 7.1 Water Use)**

- Annual plants often require more irrigation than perennials. Many perennials require some additional maintenance such as seasonal pruning, which should be taken into account in maintenance plans.

- Group plants with similar water-use needs by determining which areas of the site should receive a higher level of care than others and, during drought periods, more irrigation. Coordinate these areas with the irrigation plan. For example:

  - High water-use – Vegetables, fruit trees, lawns, exotic shrubs, flowering herbaceous annuals and many bulbs. [27]

  - Medium water-use – Hardy vegetables, fruit trees and vines, many herbs, some exotic shrubs, most gray or hairy leafed plants, roses and daisies. [27]

  - Low water-use – Most natives including. Succulents and cacti, olive trees and some exotic ornamentals. [27]

- Minimizing lawn areas. In most gardens, lawns consume up to 90 per cent of outdoor water.[27] To reduce outdoor water-use, lawns should be replaced with shrubs, groundcover, perennials or mulched garden beds. Plant drought tolerant species.

- In order to irrigate lawns efficiently, design them with relatively small perimeter areas and in flowing, rounded shapes. Long, skinny, or oddly shaped turf areas are difficult to negotiate with most irrigation equipment.

4.1.8.1.1. Soil improvement considerations for water efficiency

The main considerations for soil water-efficient improvements are discussed as followed:

- Finer soils have a greater capacity to hold water due to their greater particle surface area. There are three main soil types: sand, loam and clay. Sandy soils drain rapidly, clay soils hold water but make it difficult for many plants to grow.

- A soil with plenty of organic matter and a mixture of fine and coarse particles that form into small composite particles (called ‘peds’) is ideal. The addition of organic matter (such as manure, leaf mould, compost, gypsum and other compounds) by digging them into a depth of 15-20cm can improve soil condition, water retention and drainage. Hardy, deep-rooted plants can help break up poor soils. [27]

- Water crystals and soil wetting agents can increase soil moisture for use by the plants. Soil wetting agents allow water to penetrate dry soil surfaces and prevent run-off, while water crystals help store the water in the soil.

- Mulching around plants saves water by preventing evaporation and reducing run-off. Mulching limits weed growth and can improve soil conditions. Mulch can be in the form of leaves and grass clippings, sawdust, rocks and gravel, straw and other crop residues, bark and woodchips. [27]

Figure 45 Woodchips Mulch **(Reardon & Downton, 7.1 Water Use)**

- Humectants, a moistening agent, attract moisture from air spaces in the soil. These are particularly effective in sandy soils. Installing soil moisture sensors to cutoff switches when it rains and adjust watering duration according to soil moisture levels. Soil wetting agents allow water to penetrate deeply into soil.

4.1.8.2. Water-efficient irrigation techniques

Irrigation system efficiency varies widely, for example, high-efficiency drip irrigation systems can be 95% efficient, while sprinkler or spray irrigation systems are only 60% to 70% efficient. [33]

4.1.8.2.1. Drip irrigation

Drip irrigation is the slow application of water directly to the plant's root zone using "drippers", which are also referred to as "emitters". Maintaining an optimum moisture level in the soil at all times results in less water lost to the sun, wind and non-growth areas. The advantages for an eco-resort are:

- The root zone is maintained at its ideal moisture level, combining the proper balance of water and air for a very efficient irrigation system.

[33] Council, U. G. (2005). *LEED-NC v2.2 Reference Guide.* Washington, DC: U.S. Green Building Council.

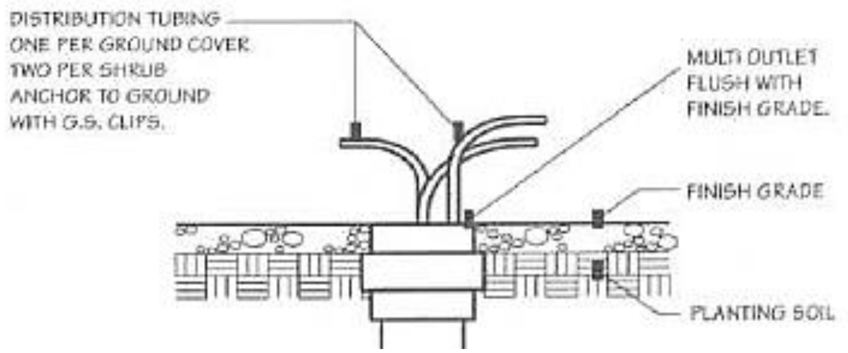


Figure 46 Typical drip emitter **(Harris, Dines, & Brown, 1998)**

- Drip irrigation flow rates are in liters per hour not per minute, because of the low flow from each emitter. Drip emitters are usually rated at 4-8 liters per hour.

The primary element of a drip system is the emitter, of which several types are available. Some emit droplets of water, while others (referred to as aerosol emitters) emit minute streams of water. Emitters fall into two categories:

- Non-compensating emitters will release a set amount of water at a given pressure. [32]

- Compensating emitters are designed for pressure differences and will emit a set amount of water through each emitter at a uniform rate within a particular pressure range.[32] For maximum efficiency in water use, these emitters are recommended in all systems with long pipe runs or different elevations.

4.1.8.2.2. Sprinkler system

Sprinkler systems are the most widely used type of irrigation. The first step in the selection and layout of sprinkler heads is to divide the area to be irrigated into zones that have similar water requirements, e.g., lawn areas, shrub areas, and different exposures to the sun. Where possible, the use of large-radius heads should be considered first. Triangular spacing is more efficient than square spacing. [32]

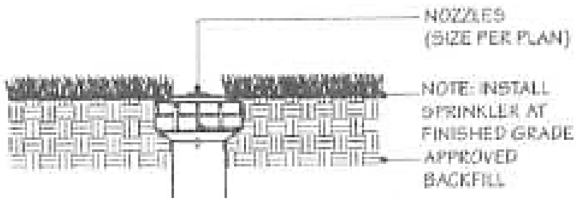


Figure 47 Typical pop-up spray head **(Harris, Dines, & Brown, 1998)**

The most important objective when laying out sprinklers is the even distribution of water. Sprinklers that produce different precipitation rates should not be used in the same zone. Sprinkler-to-sprinkler dimensions should be based on deviations of wind velocity. It is recommended to isolate heads with similar arcs in one zone and to balance the zones at the controller; for example, full-head zones should water 4 times as long as quarter- head zones. [32]

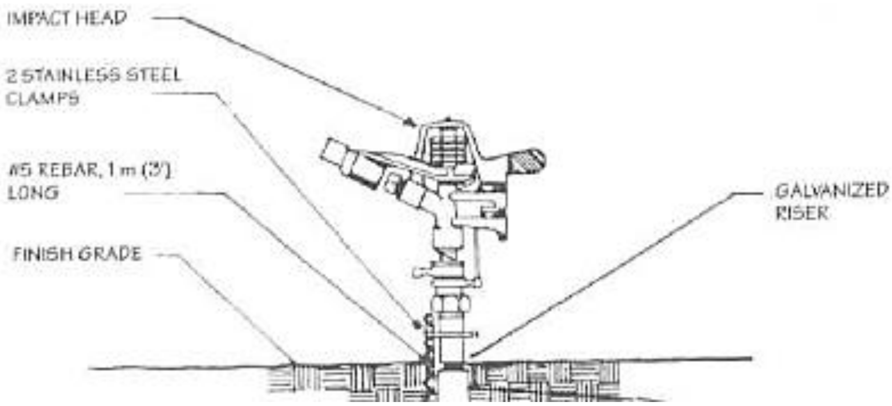


Figure 48 Typical impact head **(Harris, Dines, & Brown, 1998)**

Flood and stream bubblers are often used to water small shrub areas and to water plants that prefer dry foliage. Bubblers emit water at a much faster rate than the soil can absorb it and are used only to flood an area rapidly. Bubblers do not work well on sloping ground. Pressure-compensating bubblers should be used in areas with potential pressure fluctuations or high pressures.

4.1.8.2.3. Quick-Coupler system

Often referred to as a snap-valve system or manual system, a quick coupler is a valve which is opened when a quick-coupler key is inserted. As the key is rotated, an increase in water volume is realized. A hose or sprinkler head can be attached to the key to distribute the water as required. For reasons of water economy and lack of control, the use of quick couplers on large turf-grass zones is declining in favor of a fully automatic sprinkler system.

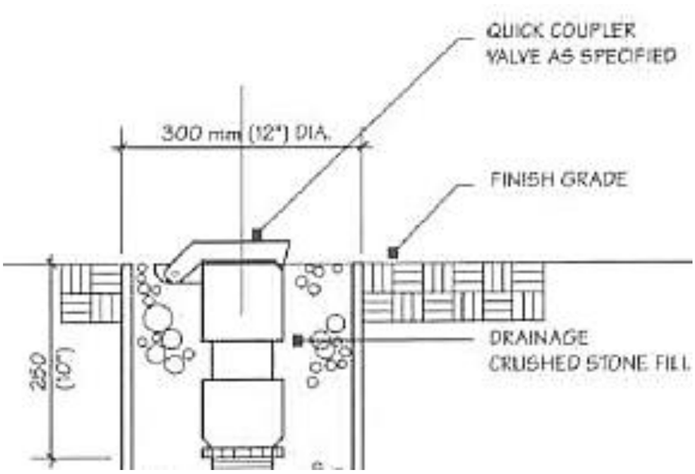


Figure 49 Quick-coupler valve **(Harris, Dines, & Brown, 1998)**

Irrigation method	Improper water management (1)	Evaporation from plant surface	Evaporation from soil surface	Evaporation from water surface (2)	Runoff and deep percolation	Leakage from conveyance system
Sprinkler	√	√	√	√	√	√
Drip (Micro)	√	√	√		√	√
Subsurface	√				√	√

1. Improper water management includes applying water where it is not needed or in excessive amounts, and the water table is maintained too high or too low.
2. Evaporation from the water surface will occur when water is applied in excessive amounts resulting in ponding.

Table 20 Factors affecting water losses during water application in landscape irrigation **(Asano, Burton, Leverenz, Tsuchihashi, & Tchobanoglous, 2007)**

Table 20 shows that subsurface irrigation is the most water-efficient, by avoiding all possible evaporation processes.

4.1.9. Issues influenced by water-efficient techniques

Using water-efficient techniques influences some issues categorized as followed:

4.1.9.1. Cost issues

Water-conserving fixtures that use less water than requirements in the Energy Policy Act of 1992 may have higher initial costs. Additionally, there may be a longer lead time for delivery because of their limited availability. However, installation of water- efficient fixtures and equipment can result in significant, long-term financial and environmental savings. [33]

4.1.9.2. Economic issues

Reductions in water consumption minimize overall building operating costs. Reductions can also lead to more stable municipal taxes and water rates. By handling reduced water volumes, water treatment facilities can delay expansion and maintain stable water prices.

Accelerated retrofits of high-efficiency plumbing fixtures through incentive programs has become a cost-effective way for some municipalities to defer, reduce or avoid capital costs of needed water supply and wastewater facilities.

4.1.9.3. Environmental issues

The reduction of potable water use in buildings for toilets, showerheads and taps reduces the total amount withdrawn from rivers, streams, underground aquifers and other water bodies. Another benefit of potable water conservation is reduced energy use and chemical inputs at municipal water treatment works.

Water use reductions, in aggregate, allow municipalities to reduce or defer the capital investment needed for water supply and wastewater treatment infrastructure. These strategies protect the natural water cycle and save water resources for future generations.

4.1.9.4. Regional issues

Local building and health codes/ordinances differ in how alternative plumbing fixtures, such as dual-flush water closets, composting toilets and non-water using urinals are handled. It is critical to confirm acceptability of non-traditional approaches with code officials prior to commitment to specific water saving strategies.

Supply water quality from recycled water systems should also be considered in fixture selection. Project teams should identify if minimum supply water quality standards have been established for specific fixtures by manufacturers.

When recycled graywater or collected rainwater is used with plumbing fixtures designed for use with municipally supplied potable water, it is good practice to verify that supply water quality is acceptable and will not compromise long-term fixture performance.

4.2. Non-potable water usage

Water conservation strategies such as biological wastewater treatment, rainwater catchment and graywater plumbing systems often involve more substantial investment. Non-potable water volumes can be used for landscape irrigation, toilet and urinal flushing, custodial purposes and building systems. Utility savings, though dependent on the local water costs, can save thousands of dollars per year.

The sources of non-potable water are:

- Used water (wastewater) from buildings, sports venues, and public facilities, potentially separated into black and gray or even yellow water streams.

- Stormwater stored and treated by best management practices in the landscape and underground, including infiltration into groundwater.

- Collected rainwater.
- Desalination of seawater.
- Irrigation return flow after infiltration into groundwater zones.
- Groundwater pumped from underground spaces and parking garages.

- Condensation from air conditioners, (which, however, has the chemistry of distilled water lacking minerals and cannot be used directly as potable water, in spite of its purity).

4.2.1. Groundwater

The development of high-yield wells can lower water tables significantly and draw water from considerable distances. The choice of system generally depends on regional geohydrologic conditions, with wells usually being the most cost-effective alternative for water acquisition.

4.2.1.1. Site characteristics and groundwater flow effects on wells

In highly permeable soils, where groundwater can move easily, the water table surfaces are likely to be quite flat and only minimally reflect the shape of the ground surface, but in less permeable soils the water table is more likely to reflect the contour of the ground surface.

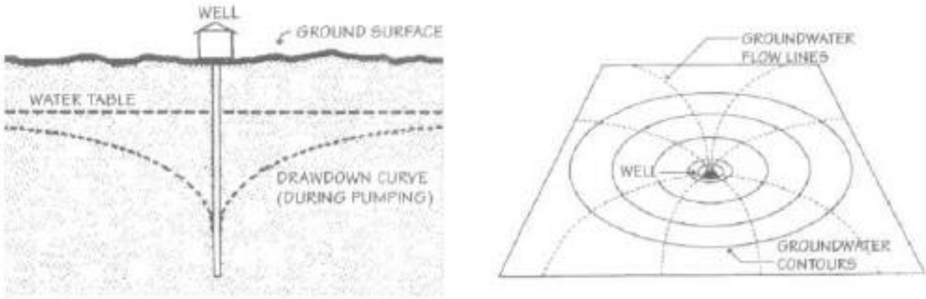


Figure 50 Section and oblique view for a drawdown cone in uniformly permeable sands and a flat water table **(Harris, Dines, & Brown, 1998)**

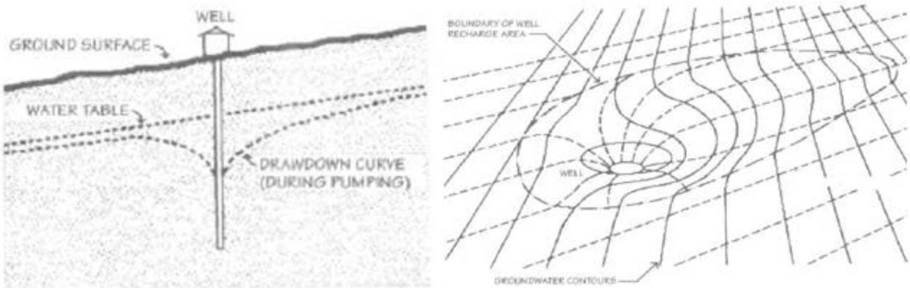


Figure 51 Section and oblique view for a drawdown cone in uniformly permeable sands and a uniformly sloping water table **(Harris, Dines, & Brown, 1998)**

4.2.1.2. Well size effect on groundwater flow

Aquifers that have been satisfactorily serving low-yield wells cannot be assumed to be suitable for high-yield wells.

4.2.1.3. Groundwater usage constraints

The planning of a high-yield well should include consideration of the following development constraints:

4.2.1.3.1. Proximity to seawater

Wells in seacoast environments must maintain adequate water table levels. If the water table falls to mean sea level, brackish water enters the well, and ruins it for water supply purposes.

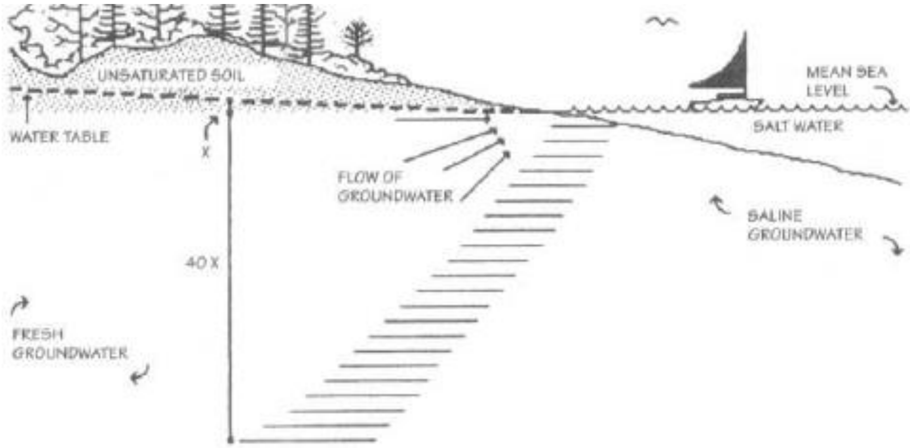


Figure 52 Groundwater environment at seacoast before well existence
(Harris, Dines, & Brown, 1998)

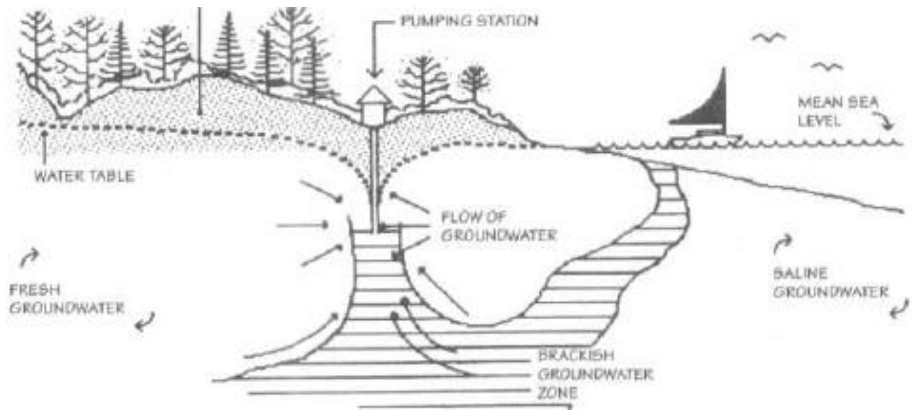


Figure 53 Effect of well drawdown below mean sea level on groundwater flow
(Harris, Dines, & Brown, 1998)

4.2.1.3.2. Urban land use

Contamination from wastewater is a concern in areas with old or failing cesspools, leaching fields, etc. No well should be developed in areas where its cone of depression would include any significant number of old buildings, unless site analyses demonstrate that no contamination problem exists.

4.2.1.3.3. Proximity to organic deposits

In areas where wells are adjacent to organic deposits, withdraw of significant volumes may increase the iron and/or manganese content of the well, ruining it for water supply purposes. Resting the well will often correct the problem.

4.2.1.3.4. Industrial and waste contamination

The denser the development, the higher the concentration of nitrates from on-site wastewater disposal which may pollute groundwater. Acceptable densities are a function of rainfall amounts, soil permeability and infiltration rates. Active or vacant Industrial sites, including processing, chemical storage, shipping, or waste disposal, should not be included in the recharge cone of any potable well, unless site analyses demonstrate that no contamination problem exists.

4.2.2. Desalinated water

Reverse Osmosis (RO) desalination plants consume less energy than Evaporation (EV) plants. Hybrid plants utilize both EV and RO units. Since the eco-resort desalination unit will be situated along the coast, there is enough wind for powering a RO unit with wind turbines. Photovoltaic (PV) systems are more expensive than wind turbines. [9] The main aspects of water desalination are discussed as followed:

- Avoid sophisticated technology or large machines, since these produce too much concentrated high-salinity waste which may not be dumped into the sea.

- In areas where water is scarce, consider the pros and cons of a reverse osmosis plant to convert seawater for all eco-resort water needs; normally it is considered inappropriate for “environmentally sensitive” development.

4.2.2.1. Solar stills

Solar stills are used for treating saline groundwater and seawater for drinking purposes. Solar stills mimic the process where the water from the ocean evaporates, condenses, and falls as rain. Solar stills effectively eliminate water-borne pathogens, salts, minerals and heavy metals. Water used in a still could be from poorer quality water sources such as seawater, saline bore water or recycled water.

Concentrated Solar Power Distillers (CSP) are used for the desalination of sea water. All CSP technologies (Parabolic Trough, linear Fresnel, Central Receiver, Dish Stirling) are suited for generating electricity and heat and can be therefore combined with reverse osmosis as well as with thermal desalination systems. The basic idea is that the solar heat, collected by reflecting surfaces, is used to raise the temperature of sea water, passing in pipes, causing it to evaporate. The water vapour that comes off is then condensed as fresh water.

Although CSP water desalination systems require high initial costs, their applications are highly recommended as they depend on the most available source of renewable energy (solar power) in the Red Sea region.

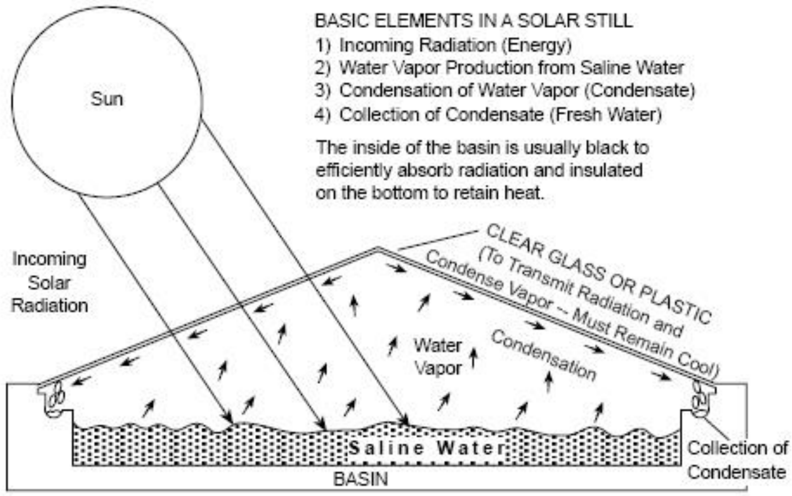


Figure 54 Basic elements in a solar still **(Corr, Adams, & Boynton, 2009)**

4.2.3. Rainwater

Rainwater systems provide non-potable water suitable for landscape irrigation, flushing toilets and urinals, and process water needs. Rainwater systems are often less expensive than graywater systems. Rainwater collected from roofs or site can displace potable water demand.

In general, components in a rainwater collection system serve one of the following functions: catchment, conveyance, purification, storage and distribution.[31] On a building site scale, water catchment systems can incorporate bio-swales and retention ponds.

Collecting and using precipitation is an excellent way to minimize the need for utility-provided water. Rainwater collection has long been utilized in arid parts of the world. Particularly in areas where populations are dispersed, rainwater collection offers a low-cost alternative to centralized piped water supply. The following figure defines the required horizontal areas of catchment needed for achieving various catchment yields in different precipitation rates.

Due to rainwater scarcity in the Red Sea region, the collection of rainwater will not be applicable.

4.2.4. Wastewater

As water becomes a more precious resource, we are seeing more buildings with systems for separating discarded wash water. After a minimum of filtration within the building, wash water can serve such secondary uses as the flushing of toilets or the watering of landscape.

Table 21 shows that natural treatment systems differ from conventional processes in that they require less or no energy either in their construction or in operation, making them highly sustainable with a small carbon footprint. However, such systems offset the need for energy and expensive electromechanical equipment by utilizing greater areas of land, making them more important in warmer climates where land is comparatively cheap. [34]

		Natural treatment	Activated sludge
Applicability		Rural, small populations	Urban, large populations
Sustainability factors	Energy	Natural or renewable	Electricity
	Construction materials	Soil bunds, butyl liners	Concrete, steel, plastic
	Aeration	Diffusion, photosynthesis	Mechanical aeration or diffusers
	Chemicals usage	None or very low	Moderate to high
	Chemical types	Lime	Lime, metal salts, polyacrylamides
	Carbon footprint	Low	Very high
	Wildlife value	High	Low
Operational factors	Sludge production	Low, on-site disposal	High, off-site disposal
	Odour	Low	Moderate to high
	Noise	None or very low	Moderate to high
	Aerosol formation	None	High
	Controllability	Low to moderate	High
Design and costs	Design layout	Dispersed	Compact
	Land area	High	Low
	Capital cost	Low to moderate	High
	Operational cost	Low	High

Table 21 Comparison between natural treatment and the activated sludge systems **(Gray, 2010)**

[34] Gray, N. F. (2010). *Water Technology: An Introduction for Environmental Scientists and Engineers - 3rd edition.* Oxford: IWA Publishing.

Treated water can be used for the following purposes:

- As a substitution in applications that do not require high-quality water supplies, such as toilet flushing irrigation, street and car washing, and pavement cooling to reduce the urban heat island effect.
- For augmenting water sources and providing alternative sources of supply to assist in meeting present and future needs.
- For protecting aquatic ecosystems by providing ecological flows and avoiding ephemeral flows created by excessive withdrawals. [35]
- As a source of cooling or heating.
- For recharging wetlands and groundwater to enhance available water and/or prevent subsidence of historic buildings. [35]

The necessity and availability of wastewater reuse and treatment strategies is heavily influenced by the project's size and location. In remote locations, it may be more cost-effective to use an on-site wastewater treatment system than to extend infrastructure.

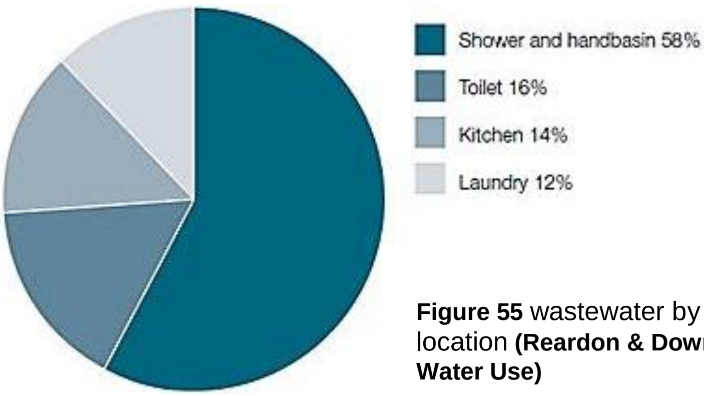


Figure 55 wastewater by indoor location **(Reardon & Downton, 7.1 Water Use)**

Figure 55 proves that showers and hand basins have the highest rate in wastewater production. Toilets come in the second place. Kitchens and laundries have the third and fourth ranks.

Regulatory guidelines for water reclamation usually pertain to treated water-quality and treatment requirements, water-monitoring requirements, reliability of treatment facilities, storage requirements, irrigation application rates, groundwater monitoring and property-line setback distances for applications. The objective of these regulations is usually to maximize resource benefits while protecting environmental and public health.

[35] Novotny, V., Ahern, J., & Brown, P. (2010). Water centric sustainable communities: planning, retrofitting,an building the next urban environment. New Jersey: John Wiley & Sons, Inc.

4.2.4.1. Aspects for wastewater treatment techniques

A wide variety of onsite wastewater treatment systems may be chosen for a given site. The primary criteria for selecting a design are:

- The physical aspects of the site.
- A destination for treated effluent and stormwater.
- The volume and nature of wastewater that is to be generated.
- The regulator's decisions about disposal routes and effluent quality.
- Protection of public health while preventing environmental degradation.
- Cost and ease of operating and maintaining the system.
- Fate and toxicity of any residuals resulting from the treatment.
- Disposal system must be considered in the selection process.

The environmentally and economically preferred route is usually to 'soak-away', unless wastewater volumes are too great for the available land area or the site is otherwise unsuitable (e.g. high water table, groundwater protection zones, impermeable soil, steep slopes, bedrock, nearby private water supplies).[14] If a 'soak-away' is not possible, then a suitable drain or watercourse must be identified and an appropriate effluent quality determined.

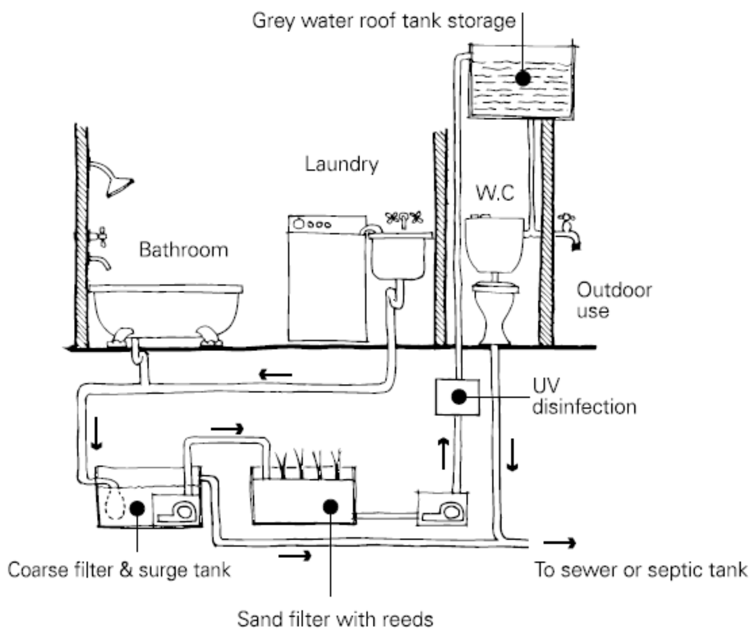


Figure 56 an example of a wastewater system **(Reardon & Downton, 7.1 Water Use)**

Low-lying areas on the natural landscape are often associated with wetlands and floodplains of rivers, streams, ponds and reservoirs. Soils in low-lying areas are wet for long periods of time and are often poorly drained, ponded or flooded. These soils are not suitable for on-site sewage disposal. [29]

If there is a requirement for sewage effluent to be treated to a very high standard, then the cost of a reuse scheme may be partly covered by necessary upgrade costs. Technologies such as Membrane Bio-Reactors (MBRs) and Sequencing Batch Reactors (SBRs) are commercially available and produce high-quality effluents suitable for non-potable reuse after disinfection. [14]

The different treatment systems can vary greatly in terms of the treatment processes used, that may be biological, chemical or mechanical treatment. The qualities of treated water they produce can vary considerably, as well as initial cost. Projects that plan to treat wastewater on-site should consider a treatment system such as:

4.2.4.1.1. Septic tanks

Buildings that lie beyond the reach of metropolitan sewers must treat and dispose of their own sewage. This was formerly accomplished using a cesspool, a porous underground container of stone or brick that allowed the sewage to seep into the surrounding soil.

The more satisfactory successor is the nonporous septic tank, which is composed of the following four basic components: [29]

1. Building sewer.
2. Septic tank.
3. Distribution box.
4. Drain field (or leach field).

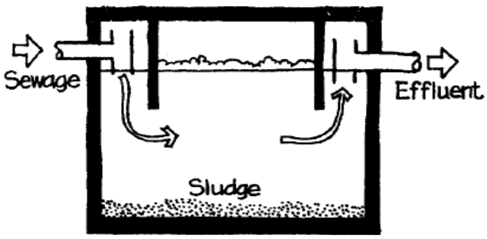


Figure 57 a septic tank concept **(ALLEN, 2005)**

The septic tank is configured in such a way that it holds sewage for a period of days, allowing it to decompose anaerobically and to separate into a clear, relatively harmless liquid effluent and a small amount of solid mineral matter, which settles to the bottom. Septic tanks can be used in combination with a percolating filter, RBC and/or reed bed.

In its simplest form, the septic tank consists of a single chamber with a single input and output. They can be of any shape although they are normally rectangular in plan, with two chambers and made out of concrete. The tank consists of three separate zones, a scum layer on top of the clarified liquid with a sludge layer in the base.

Most drain fields are installed in the native soil material found on-site. In the case of filled systems, native soil material is removed and the drain field is constructed above grade in gravel fill material. Filled systems are required at locations where on-site evaluations show that either the groundwater table is less than 1 m from the original ground surface, or the depth to a ledge - impervious soil layer - is less than 2 m from the original ground surface. [29]

Septic tanks can be used following the guidelines below:

- Performing soil tests to determine the percolation rate of the ground, or the rate at which the leachate can be absorbed. The leachate can provide irrigation for plants, but beware of the tendency for fast growing roots to clog pipes.

- Designing septic tanks and leach fields to accommodate the volume of waste flow.

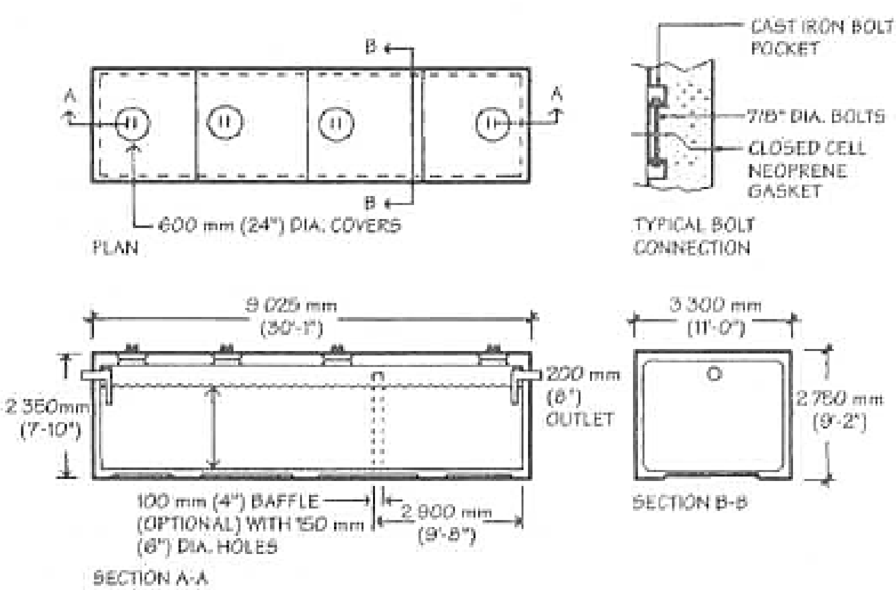


Figure 58 Typical precast septic tank (15000 gal) **(Harris, Dines, & Brown, 1998)**

- The septic tank system does not actively treat wastewater to remove disease-causing pathogens. Effluent from a septic tank should be disposed underground at soil depths greater than 300mm. [27]

- Providing an adequate depth of unsaturated soil between the effluent leaching device and the water table [typically 1 to 1.2 m]. Many jurisdictions will allow mounded leaching fields for sites with high water tables, and leaching pits or leaching trenches for hilly sites. [32]

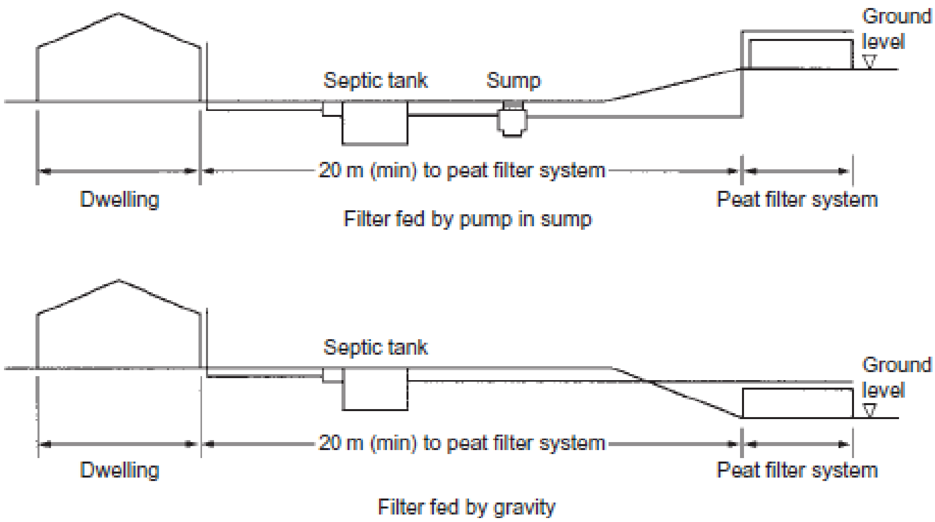


Figure 59 Filter feeding types for septic tanks **(Gray, 2010)**

- Protection against breakthroughs of untreated effluent is typically provided by setting the leaching facilities back 15 to 30 m from wells and surface waters. [32]

- Leaching systems should function well for about twenty years before requiring resting. Site planning should provide for the layout for two parallel systems, although only one may be constructed initially.

- Once built, periodic pumping and inspection of existing septic systems is the key to maximizing the longevity and performance, and reducing the environmental impacts of the system. As a rule of thumb, septic tanks should be inspected yearly and pumped every 2−4 years. [29]

- All drain fields accumulate organic slime material (biomat) at the junction of the drain field and native soil. Surfacing of effluent can occur when wastewater volume to the drain field exceeds rate of movement through the biomat and into the surrounding soil. Biomats develop rapidly in silty, clay or dense compacted soils. [29]

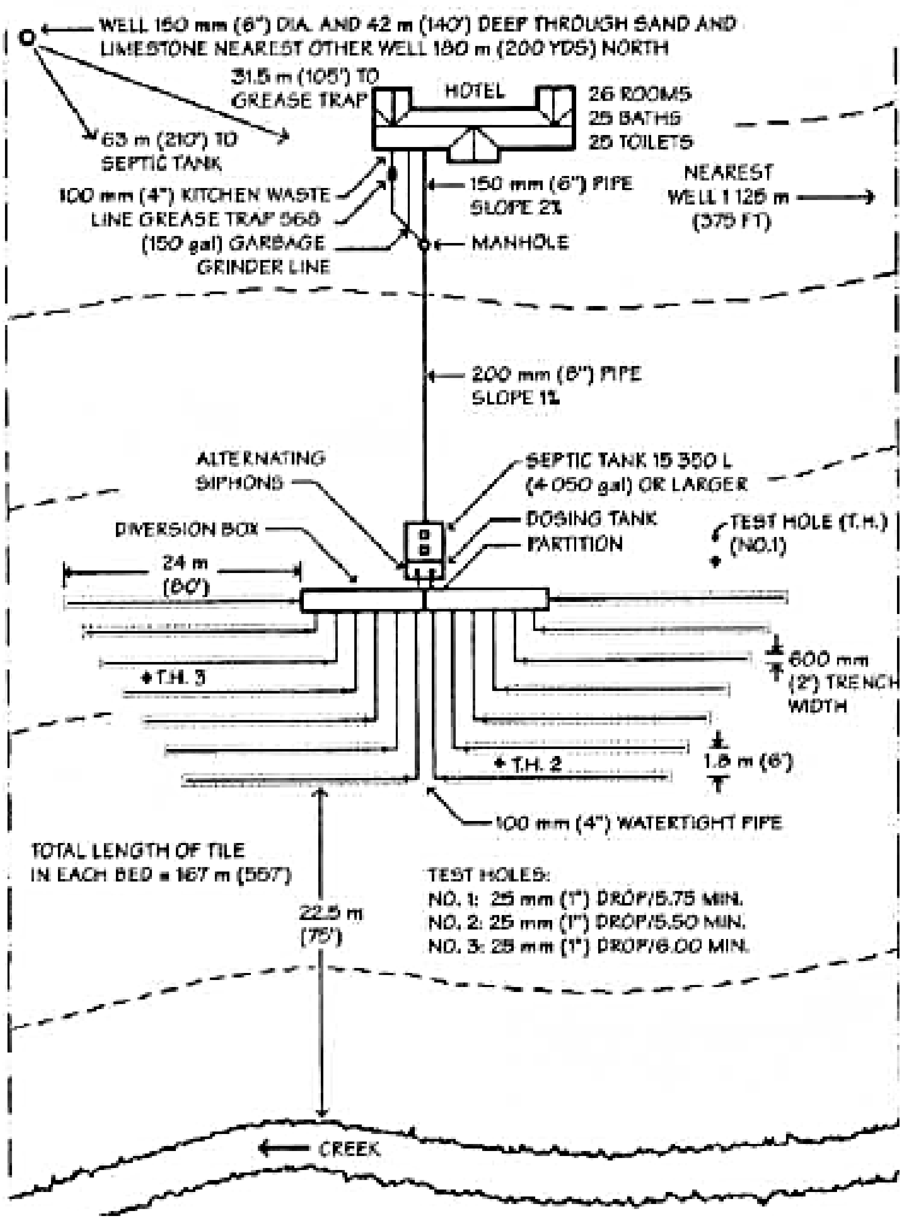


Figure 60 Principal elements of a large leaching system
(Harris, Dines, & Brown, 1998)

4.2.4.1.2. Anaerobic waste treatment

Anaerobic waste treatment can be used following the guidelines below:

- Considering having large, isolated treatment and disposal areas as slow treatment means longer holding periods (shallow depth tanks).
- Disposing effluent in an underground system that passes it through selected undisturbed soil profiles to filter and remove nutrients before returning to the water cycle. Ensure that stored effluent receives some aeration to facilitate odor-free recycled water.

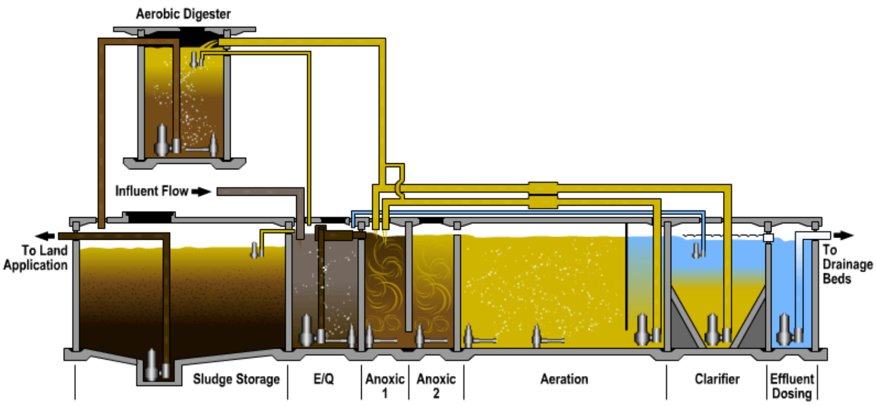


Figure 61 an anaerobic waste treatment plant **(Reardon & Downton, 7.1 Water Use)**

4.2.4.1.3. Aerobic waste treatment

Aerobic waste treatment can be used following the guidelines below:

- An economical aerobic latrine can be built using local materials. Briefly, excrement is collected in a five-gallon bucket emptied into an aboveground, vaulted composting bin made of wood, with a thatched roof. Each vault measures 1.5 m x 1.5 m x 1.5 m. [22]
- After emptying the bucket into the compost bin, the fresh deposit is covered with dry leaves, grass or hay to eliminate odors and flies. One vault is filled at a time, then it is left and the other vault is used. The pile should not be turned or actively aerated. Aerobic conditions are maintained inside the pile by air trapped in the large, bulky cover materials.

4.2.4.1.4. Constructed wetlands

Natural wetlands (e.g. swamps, bogs, marshes, fens, sloughs, etc.) have been developed around the world to help provide water quality improvement, flood protection, shoreline erosion control, wastewater treatment and recreation opportunities.

Constructed wetlands are artificial wetlands used for waste treatment. They are shallow ponds (0.6 to 1.5 m deep) open to the sun and wind, used to retain sewage for about a month.[32] It relies entirely on natural processes and, with favorable topography, on gravity flow. The pond can usually be built of locally available or on-site materials. Ponds can be contained by seeded earthen berms of clayey or silt soils.

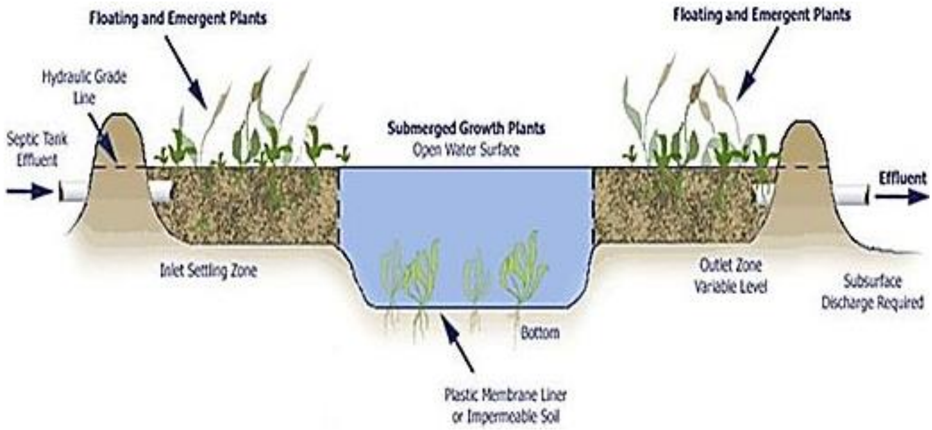


Figure 62 an illustration for a constructed wetland
(Reardon & Downton, 7.1 Water Use)

The solids settle to the bottom and decompose anaerobically, but their odor is contained and absorbed by the overlying aerated water. The mineral nutrients released in the decomposition, together with the sun shining on the pond's surface, support a vigorous growth of algae. The algae produce oxygen; this, along with the oxygen absorbed by the ponds surface, keeps the upper layers of the pond fresh and odor-free. Constructed wetland treatment systems generally fall into one of two general categories:

- *Subsurface flow systems* create subsurface flow through a filter, keeping the water being treated below the surface, and helping to avoid the development of odors and other nuisance problems. [22]

- *Free-water surface systems* are designed to simulate natural wetlands, with water flowing over the soil surface at shallow depths. [22]

Both types of wetland treatment systems typically are constructed in basins or channels with a natural or constructed subsurface barrier to limit seepage.

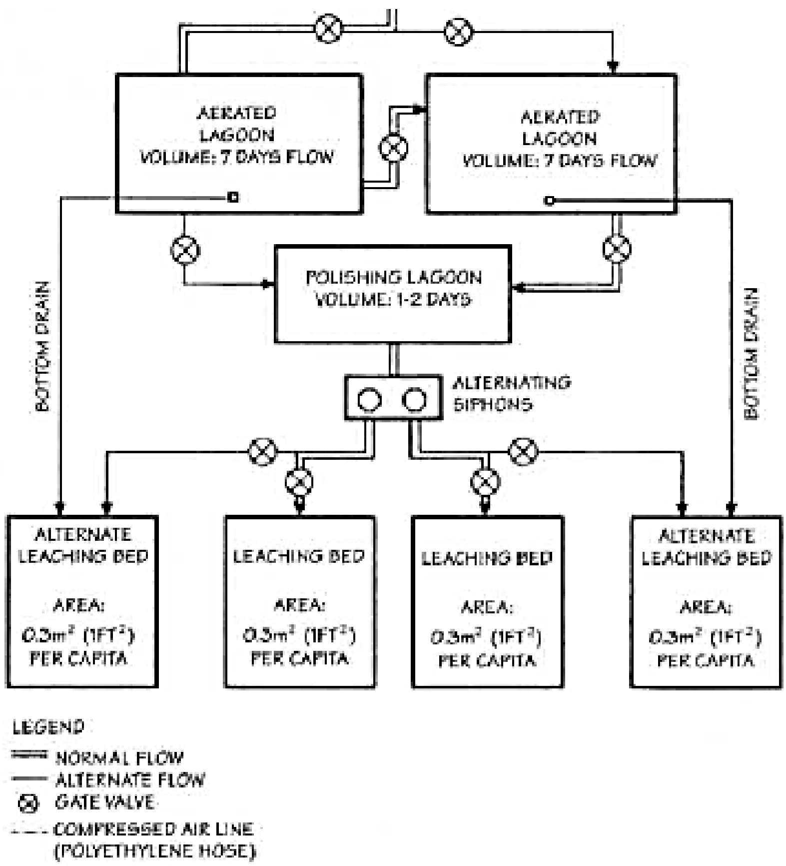


Figure 63 Typical aerated lagoon (pond) system **(Harris, Dines, & Brown, 1998)**

The effluent from the stabilization pond is siphoned off the top to a polishing lagoon (about 1 day flow) and then dosed onto sand filters at rates up to 0 .95 L/ m^2 per day.[32] The ponds do have to be drained and cleaned at infrequent intervals (up to 20 years) and the leaching beds do need to be alternated and rested, if they show signs of clogging. The land used for lagoon systems and surface infiltration cannot be used for other purposes.

4.2.4.1.5. Living machines (Package treatment system)

Living machines are engineered waste treatment systems designed to process a building's sanitary drainage on site. Most common Living Machines work as a hydroponic system that relies on bacteria, plants, and an overflow wetland to clean wastewater. It consists of two anaerobic tanks, a closed aerobic tank, three open aerobic (hydroponic) tanks, a clarifier, an artificial wetland and a UV filter. The treated water can be reused for selected applications.

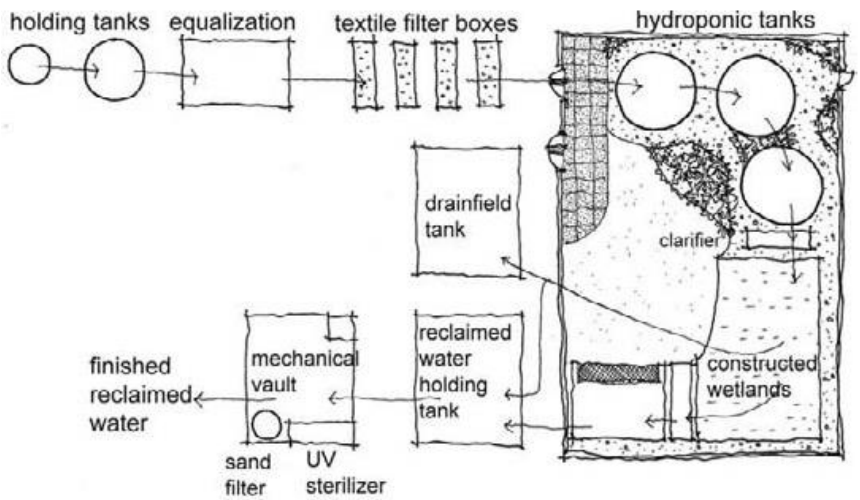


Figure 64 Typical components and sequence of flows in a Living Machine
(Kwok & Grondzik, 2007)

Design procedures of Living machines are discussed in Appendix A. Living machines can be used following the guidelines below:

- Separation of the Living Machine (at least from the thermal, airflow, and occupant circulation perspectives) from the building being served by the system is recommended.
- Nitrification, which occurs in the open aerobic tanks, has an optimal temperature range of 19–30 °C.[31] Therefore, these particular tanks must be housed within a temperature-controlled facility for optimal performance.
- Living Machines have a large footprint, accommodating these spatial and volumetric demands will be a key architectural design concern. Spatial requirements for different system capacities are shown in Table 22. Living Machines require exterior space, preferably adjacent to the building being served, where the closed aerobic tanks can be buried. These tanks should be accessible to maintenance.

SYSTEM CAPACITY	AEROBIC TANK DIMENSIONS	CLARIFIER DIMENSIONS	WETLAND DIMENSIONS
Small: 2500 gpd [9460 L/d], use 3 aerobic tanks	diameter 1.8 m	diameter 2.4 m	4.6 x 9.1 m
	height 0.9 m	height 0.9 m	depth 0.9 m
	1500 gal [5680 L]	700 gal [2650 L]	
Medium: 10000 gpd [37850 L/d], use 6 aerobic tanks	diameter 2.4 m	diameter 2.4 m	6.1 x 6.1 m
	height 1.2 m	height 1.2 m	depth 1.2 m
	depth 2.4 m	depth 2.4 m	
	3000 gal [11,360 L]	3000 gal [11,360 L]	
Large: 35000 gpd [132475 L/d], use 4 aerobic tanks	diameter 4.3 m	diameter 4.3 m	custom sizing required
	height 0.9 m	height 0.9 m	
	depth 3 m	depth 3 m	
	10000 gal [37850 L]	10000 gal [37850 L]	

Table 22 Approximate dimensions of Living Machine components for three system sizes (capacities) **(Kwok & Grondzik, 2007)**

- Living Machines produce liquid output generally equal in volume to the potable water intake of the building. This water discharge must be accommodated on site. A fair amount of vegetation is also produced and should be beneficially used on site upon catchment. There are landscape design implications for aesthetic possibilities for the various processing tanks and their enclosure.

4.2.4.1.6. Evapotranspiration treatment system

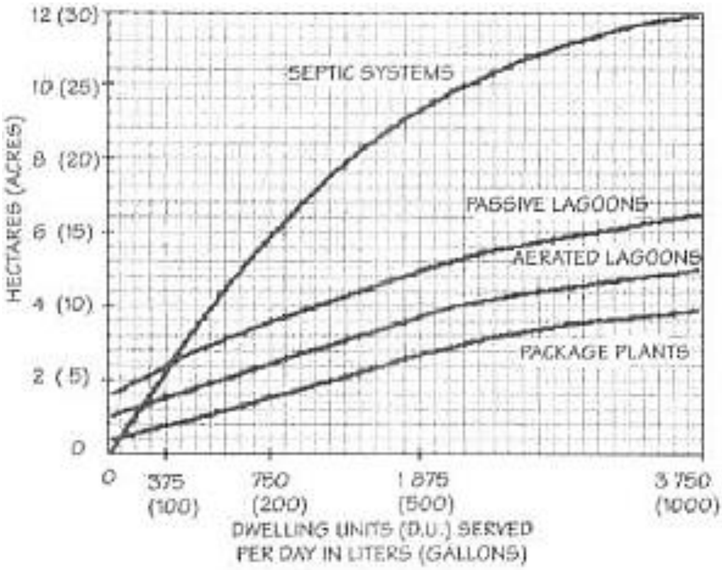
For sites with limited absorptive capacity where the usage is limited to the growing season, it is possible to dispose of a high proportion of wastewater by evapotranspiration**,** where the effluent must be well aerated so that plant roots will readily take up the liquid. Evapotranspiration is not feasible with effluent from septic systems, but it can work with any aerobic effluent. [32]

The effluent can be applied by a number of methods, including sub-irrigation, surface flooding, and spray irrigation. For sub-irrigation, the system would be similar to a shallow trench infiltration system for septic effluent, but it should be constructed as close to the ground surface as possible. Like the subsurface disposal of septic effluent, the sub-irrigation method does not pose any hazards to surface use of the land.

The application rates for any evapotranspiration system are a function of temperature, hours of sunshine, wind velocity and duration, rainfall, etc. All these vary considerably with the location and the season; thus, any evapotranspiration system will require careful custom design.

4.2.4.2. Aspects for wastewater storage

Wastewater storage is recommended with requirements depend on climate, household demand for re-use water, presence and size of disposal area, and maximum daily wastewater output.



Based on:

- Flows: 750 – 1125 L (200 – 300 gal) / unit / day
- Leaching area:
  - Septic: 1.88 L (0.5 gal) / septic / day
  - Lagoon: 9.38 L (2.5 gal) / septic / day
- Buffer zones: 30 m wide
- Lagoon retention time:
  - Passive: 30 days
  - Aerated: 15 days

Figure 65 Spatial requirements for treatment systems **(Harris, Dines, & Brown, 1998)**

Figure 65 shows that after exceeding 375 L/day, the septic systems require the largest areas while package plants require the smallest areas.

4.2.4.3. Aspects for wastewater usage

The main aspects of wastewater usage are discussed as followed:

- It is important to match the graywater distribution system to the eco-resort output. There are several possible combinations of benefits and drawbacks to the various systems.

- Wastewater volume should be considered in deciding whether it is cost-effective to treat graywater and blackwater separately. Install separate lines and septic systems to reuse both gray and black waters as much as possible.

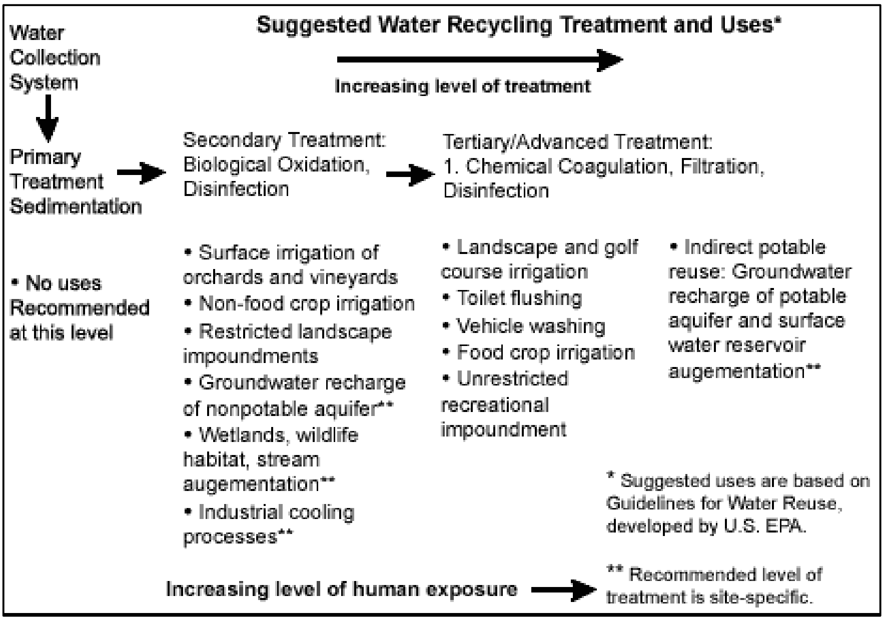


Figure 66 suggested water treatment and uses **(Novotny, Ahern, & Brown, 2010)**

4.2.5. Other non-potable water sources

4.2.5.1. Fire services testing

Routine testing of fire services can result in the discharge of large quantities of water. This water can be captured by piping and storing it in a suitable fire water holding tank for re-use in other applications, such as further fire testing or cooling tower make-up water.

4.2.5.2. Air-conditioning condensate

Air-conditioner condensate can be collected and re-used in other applications. For example, if the condensate yield is expected to be in excess of 14 grams of water per kilogram of air in 35% of the year. It is expected that 3.1 L/min will be produced from a 1,900 L/sec air-handling unit servicing 30 people. This is enough to provide 60 L/person/day. [28]

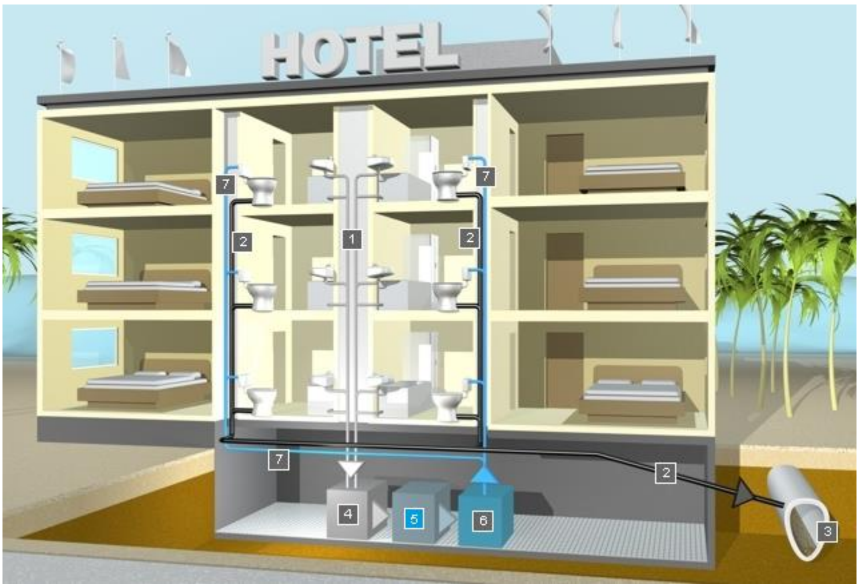
4.2.6. Non-potable water applications

Non-potable water can be used in several functions as followed:

4.2.6.1. Dual plumbing

Dual plumbing is a Piping system that supplies potable and recycled water to users from the point of connection to the distribution main to the points of use. Dual plumbing is not difficult to install, but is most-cost effective if done during initial construction. If dual plumbing lines are not installed initially, adding a graywater treatment system later can be quite expensive.

Implementing a workable graywater reuse strategy requires a building with sufficient potable water usage demands to generate adequate graywater and appropriate uses for the graywater that is generated. The building must also have space available to accommodate the infrastructure of a graywater system: additional piping to carry graywater (with a separate blackwater system) along with storage and treatment tanks.



1- Graywater sewage pipes
2- Blackwater sewage pipes
3- Main sewage pipe
4- Graywater storage tank
5- Treatment bio-reactor
6- Treated water storage tank
7- Treated water pipes

Figure 67 an example for a hotel with a dual plumbing system
(Reardon & Downton, 7.1 Water Use)

Graywater plumbing system design procedures are discussed in Appendix A.

4.2.6.1.1. Installation guidelines

Dual plumbing should be installed following the guidelines below:

- Treated water pipes shall not be run or laid in the same trench as potable water pipes. A 3 m horizontal separation shall be maintained between pressurized, buried, treated, and potable water piping. Buried potable water pipes crossing pressurized treated water pipes shall be laid a minimum of 300 mm above the treated water pipes. [36]

- To the extent permitted by structural conditions:

  - Treated water risers within the toilet room shall be installed in the opposite end of the room containing fixtures served by the potable water system.

  - Treated water headers and branches off risers shall not be run in the same wall or ceiling cavity of the toilet room where potable water piping is run.

- Dual plumbing is necessary for the use of treated water in buildings as:

  - For high-rise buildings, booster pumps are used to maintain a pressure and to pump the treated water up to the highest floor. Hydropneumatic systems may also be used.

  - For low-rise buildings, the pressure from the distribution main may be sufficient to distribute treated water.

4.2.6.2. Toilets and urinals flushing

The feasibility of using treated water depends on the plumbing and related infrastructure costs. Treated water can be used following the guidelines below:

- Treated water can be directly diverted from the shower or bathroom sink drains for immediate re-use in the toilet only. However, it should not be stored for more than a couple of hours before re-use or disposal to sewer and will require coarse filtration.

- Treated water used for toilet flushing must be odorless and colorless for aesthetic reasons, and highly disinfected for public health protection in case of accidental human contact.

[36] Asano, T., Burton, F. L., Leverenz, H. L., Tsuchihashi, R., & Tchobanoglous, G. (2007). *Water Reuse: Issues, Technologies, and Applications.* Metcalf & Eddy, Inc.

4.2.6.3. Laundry

Washing clothes at laundry facilities should be used as a part of a large treated water system following the guidelines below:

- When reusing treated water for clothes washing discoloration of clothing from dissolved organic material may be an issue. This can be avoided by installing an activated carbon filter. [27]

(a) (b)

Figure 68 A laundry facility utilizing treated water with commercial size washing machines: (a) facility building with a notice of treated water use on the door and (b) laundry machine **(Asano, Burton, Leverenz, Tsuchihashi, & Tchobanoglous, 2007)**

4.2.6.4. Air conditioning

Cooling towers used for high-rise buildings and commercial sites are usually located on the top of or behind the building where public access is limited. When treated water is used for cooling tower systems, dual plumbing systems for potable and treated water supplies must be installed.

As water evaporates in the cooling system, the concentration of dissolved solids increases. Blowdown, water removed from recirculating cooling water to control buildup of dissolved solids, is replaced with fresh water. Typically, the cycles of concentration are limited to about three to five when treated water is used because, at higher cycles of concentration, some of the salts in the recirculating water exceed their solubility limits and precipitate.

Figure 69 Sand filters used to remove residual biological flocs and precipitates following pretreatment of treated feed-water for a cooling water system **(Asano, Burton, Leverenz, Tsuchihashi, & Tchobanoglous, 2007)**

4.2.6.5. Fire protection

The use of treated water for fire protection allows the potable water pipeline to be designed for much lower peak flow rates and shorter residence times. The types of fire protection systems are outdoor systems or indoor systems.

Fire hydrants are the principal appurtenances used in outdoor systems. Hydrants are installed directly on the treated water distribution system. Fire hydrants are also used for flushing of the distribution system. The two principal types of fire hydrants used are:

- Wet-barrel hydrants are used commonly in temperate regions. [36]
- The dry-barrel hydrant is the only one that has a drain mechanism and is used commonly where freezing weather occurs. [36]

Sprinkler systems are used for indoor fire protection. The only opportunity that treated water could be used for sprinkler systems is where potable water is not readily available; treated water is rarely used in indoor sprinkler systems because:

- Dual plumbing is necessary.
- There is much greater risk of human exposure.
- Little or no potable water is saved.
- Treated water system is less economical than a potable water system.

Because water for fire protection must be available at all times, the treated water distribution system must be designed as an uninterruptible supply. The storage volume must be sufficient to meet the peak day and hourly demands. To meet fire flow requirements pipes having diameters of 150 mm (6 in.) and larger are required generally.[36] The feasibility of providing fire protection with treated water depends on the cost of the necessary infrastructure.

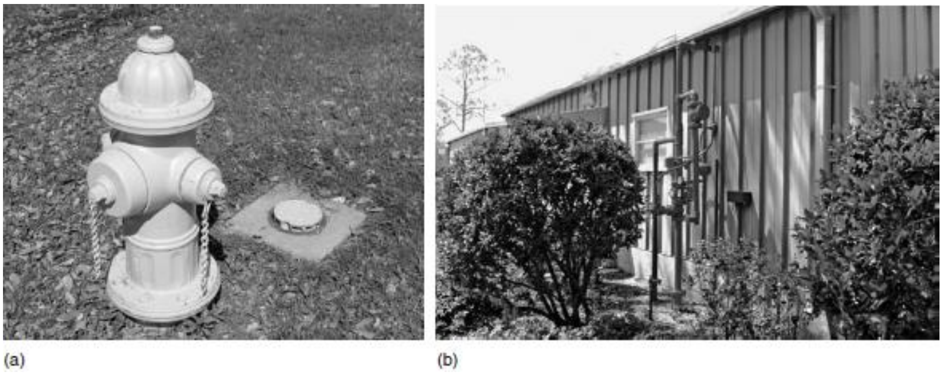


Figure 70 Examples of fire protection systems: (a) fire hydrant and (b) treated water plumbing for indoor sprinkler system **(Asano, Burton, Leverenz, Tsuchihashi, & Tchobanoglous, 2007)**

Fire hydrants are flushed periodically to ensure proper functioning and to remove solids that have accumulated in the system. It is a good practice to flush the treated water distribution network periodically because treated water systems are more likely to foster the build-up of biofilm and particulate matter as compared to potable water systems.

4.2.6.6. Landscape irrigation

The major use of treated water is for irrigation of areas such as golf courses, ornamental landscapes, and turf areas. A separate tank, filter, and special emitters are necessary in treated water irrigation systems. Types of irrigation systems that can use treated water include:

- Drip irrigation with pressure dosing, which uses a pump system to “dose” the irrigation water at regulated intervals. Sub-surface drip irrigation systems spread water evenly around the garden.
- More traditional evapotranspiration systems.
- Shallow trench systems, shown in Figure 71, which utilize distribution pipes placed close enough to the surface to allow for irrigation of plant roots.

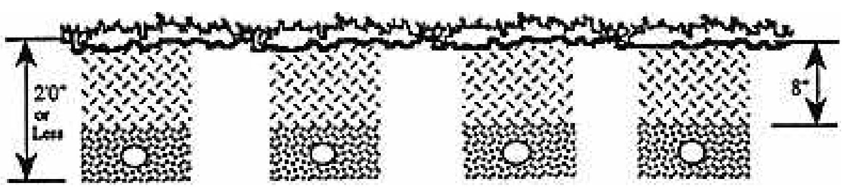


Figure 71 Shallow trench section view **(Council, 1996)**

Treated water can be used in Landscape irrigation following the guidelines below:

- Irrigation with treated water is preferred to be subsurface, although some areas permit above-ground irrigation. Factors affecting the use of treated water irrigation include soil depth and characteristics, drainage, flooding patterns and setbacks for treated water irrigation lines from property or potable-water lines.
- A common system is the 'branched drain' to mulch basins, planting areas or mini-leach fields. It is inexpensive, reliable and requires continuous downhill slope from the points of treated water generation to the points of irrigation need. It is critical that hard-plumbed lines have proper slope (at least 1/4" per foot). [9]

4.2.6.7. Public water features and road care

Public water features include fountains, small and reflecting pools, ponds and waterfalls. By using treated water, water features may be kept operating during drought years. Water should be free of odors, mosquitoes and algae.

Figure 72 Treated water used for recreational purposes: (a) San Diego, CA, commercial complex, (b) Japanese Garden, Los Angeles, CA, (c) recreational lake at Santee, CA, and (d) remains of a moat filled with treated water arround an old castle, Osaka, Japan **(Asano, Burton, Leverenz, Tsuchihashi, & Tchobanoglous, 2007)**

Treated water for dust control and street cleaning is transferred to a truck at a fill station typically located at the water reclamation plant, or from a treated water hydrant.

(a) (b)

Figure 73 Treated water use for street cleaning and dust control: (a) treated water filling station for street cleaning vehicle and (b) water truck spraying treated water **(Asano, Burton, Leverenz, Tsuchihashi, & Tchobanoglous, 2007)**

4.2.6.8. Groundwater recharge

Groundwater recharge with treated water results in the planned augmentation of groundwater for various beneficial uses such as:

- To reduce, stop, or even reverse the decline of groundwater levels.
- To protect underground freshwater in coastal aquifers against saltwater intrusion.
- To negate potential problems of land subsidence.
- To store surface water, including flood or other surplus water and treated water, for future use.

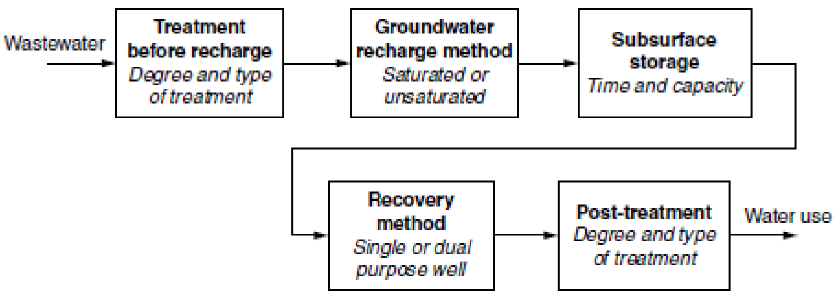


Figure 74 The five major components of a groundwater recharge system **(Asano, Burton, Leverenz, Tsuchihashi, & Tchobanoglous, 2007)**

Surface storage with treated water can result in a significant deterioration of water quality from secondary contamination and from algal blooms. Evaporation losses can also result in increased salinity, extremely in arid areas. [36]

The types of groundwater recharge now practiced may be classified as:

- Groundwater augmentation for indirect potable reuse.
- Aquifer storage and recovery.
- Control of seawater and brackish water intrusion into freshwater aquifers.

4.2.6.8.1. Groundwater recharge technologies

Three types of groundwater recharge, shown in Figure 75, are commonly used with treated water:

A. Surface Spreading

– Surface spreading is the simplest, oldest, and most widely applied method of artificial recharge. In surface spreading, treated water from the spreading basin infiltrates and percolates through the vadose (unsaturated) zone. Where hydro-geological conditions are favorable for groundwater recharge with spreading basins, water reclamation can be done by the Soil Aquifer Treatment (SAT) process.

B. Injection Wells into Vadose Zone

– Vadose zone injection wells, the newest technology, require the presence of an unsaturated zone. This method was developed as a consequence of increasing land costs in urbanized areas; the major costs associated with surface spreading are for land acquisition and the distribution system of water to recharge basins.

C. Direct Injection Wells into an Aquifer

– In direct injection, highly treated water is pumped directly into the groundwater zone, usually into a well-confined aquifer. Groundwater recharge by direct injection is practiced:

  - Where groundwater is deep or where the topography or existing land use makes surface spreading impractical or too expensive.
  - When direct injection is effective in creating freshwater barriers in coastal aquifers against intrusion of saltwater.

Both in surface spreading and direct injection, locating the extraction wells as great a distance as possible from the spreading basins or the injection wells increases the flow path length and residence time of the recharged water. [36] Vadose zone injection wells and direct injection wells are not land intensive. They may be located at different locations throughout a distribution system.

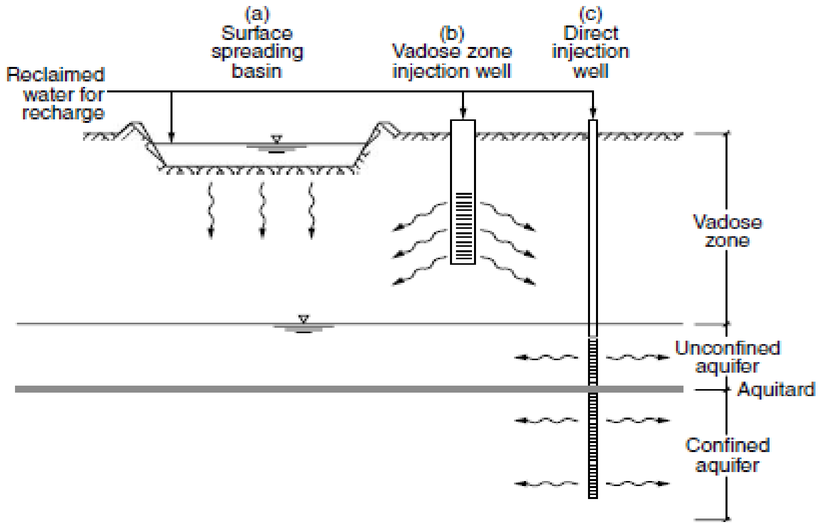


Figure 75 Principal methods for groundwater recharge: (a) surface spreading using recharge basins, (b) injection wells in vadose zone, and (c) direct injection wells into an aquifer **(Asano, Burton, Leverenz, Tsuchihashi, & Tchobanoglous, 2007)**

4.2.6.8.2. Selection of recharge system

The two most important considerations for selection of a recharge method are the type of aquifer and the availability of land. If only saturated conditions (i.e., no vadose zone) exist, then direct injection wells are required. Where an unconfined aquifer with a vadose zone is present and land is readily available, recharge basins are a logical choice; if land is not readily available then vadose zone injection wells or direct injection wells may be used.

Direct injection wells may be used with either confined or unconfined aquifers; they may also be designed to inject into several different aquifers at different depths. In addition, direct injection wells may be designed as dual purpose wells capable of both injecting and recovering water. [36]

Vadose zone injection wells are most economical when the aquifer is deep and extensive drilling is required if direct injection wells are used. For both vadose zone and direct injection wells pretreatment is required to remove solids and prevent clogging from biological growth.

Table 23 defines the advantages and disadvantages for the three groundwater recharge methods focusing on construction and operation regulations, spatial and maintenance requirements, water quality potentials and soil characteristics needed.

	Advantages	Disadvantages
Surface spreading	Relatively easy to construct and operate	Large land area required
	Primary or secondary levels of pretreatment may be satisfactory	Limited availability of suitable sites; soil characteristics are very important in site selection
		Wetting and drying cycles required to maintain infiltration rates as well as vector
		Periodic bed maintenance required
		Some evaporation losses from open water surface
		Algae growth may affect clogging
Vadose zone injection	Relatively small site required	Relatively new technology
	Negligible evaporation losses	Only short-term life cycle data available
	Less expensive technology than direct injection wells	Soil characterization required
	Greater potential for water quality improvement as compared to direct injection wells	Special design and construction of well is necessary
		Extensive pretreatment of wastewater is necessary to prevent clogging with solids and development of microbial growth
		No effective method available to redevelop clogged well
Direct injection	Relatively small site required	Relatively expensive to construct
	May be used for both injection and extraction of reclaimed water	Energy intensive; high pressure pumping required for reclaimed water injection
	High rate of reclaimed water injection	Design and construction requires greater expertise than vadose zone injection wells
	Flow in well can be reversed for maintenance and redevelopment of well	Extensive pretreatment of wastewater is necessary to prevent clogging with solids and development of microbial growth; may require a higher level of treatment than vadose zone injection wells
	Can be designed to recharge multiple aquifers	Limited additional improvement in water quality can be expected

Table 23 Advantages and disadvantages of groundwater recharge methods **(Asano, Burton, Leverenz, Tsuchihashi, & Tchobanoglous, 2007)**

4.2.6.8.3. Recovery of recharge water

Water is recovered for final use using dedicated recovery wells or dual purpose aquifer storage and recovery wells. Post-treatment of the recovered water may be required for use. The use of floodplains for groundwater recharge located near water treatment plants is often practiced.

4.2.7. Issues influenced by non-potable water techniques

4.2.7.1. Cost issues

Dual sanitary and graywater distribution piping doubles construction piping costs. In addition, local codes requiring filtration, disinfection treatment, overflow protection, etc., add to the cost of construction, operation, and maintenance; all of which should be considered by the owner when making a decision to collect graywater.

Collection and use of rainwater for non-potable water applications minimizes the need for utility-provided water, thus reducing some initial and operating costs. In some areas with a decentralized population, collection of rainwater offers a low-cost alternative to a central piped water supply. The highest cost in most rainwater systems is for water storage. [33]

A constructed wetland for wastewater treatment can add value to a development as a site enhancement. Wetlands are beneficial because they provide flood protection and stabilize soils on site. Currently, packaged biological wastewater systems have an initial high cost, relative to the overall building cost, due to the novelty of the technology.

4.2.7.2. Economic issues

Wastewater treatment systems and water recovery systems involve an initial capital investment in addition to the maintenance requirements over the building's lifetime. These costs must balance with the anticipated savings in water and sewer bills. This savings can minimize the amount of potable water that a municipality provides.

4.2.7.3. Environmental issues

On-site wastewater treatment systems transform perceived “wastes” into resources that can be used on the building site. These resources include treated water volumes for potable and non-potable use, as well as nutrients that can be applied to the site to improve soil conditions.

Reducing wastewater treatment at the local wastewater treatment works minimizes public infrastructure, energy use and chemical use.

By reducing potable water use, the local aquifer is conserved as a water resource for future generations. In areas where aquifers cannot meet the population needs economically, treated wastewater is the least expensive alternative source of water.

4.2.7.4. Regional issues

Local weather conditions should be factored into determining the feasibility of rainwater catchment systems for use in reduction of potable water for flushing. Local building and health codes vary with regards to allowance of graywater or catched rainwater for use in sewage conveyance.

Supply water quality from graywater and recycled water systems should also be considered in fixture selection. Project teams should identify if minimum supply water quality standards have been established for specific fixtures by manufacturers.

When recycled graywater is used with plumbing fixtures designed for use with municipally supplied potable water, it is good practice to verify that supply water quality is acceptable and will not compromise long-term fixture performance.

Chapter conclusions

From this chapter, conclusions can be summarized as followed:

1. Using large volumes of potable water increases maintenance and lifecycle costs for building operations. It also leads to high levels of energy consumption for heating, while also placing additional load on wastewater systems and sewage facilities.

2. Water-efficient techniques can reduce water use and pollution. Two main categories for these techniques are “Potable water applications” and “Non-potable water applications”.

3. These techniques should be selected based on design and construction requirements, adaptation with climatic conditions and achievement of water-saving, durability and suitable initial costs.

4. Potable water should be used efficiently using water efficient fixtures and techniques in bathrooms, kitchens, laundries, mechanical systems,

swimming pools and landscape. Some high water-efficient techniques include:

- Sensor-operated taps, showers, rinse nozzles and dishwashers.
- Composting, Vacuum and Incinerating toilets.
- Waterless urinals.
- Ozone laundry system.
- Sprinkler and drip irrigation systems.
- Air-cooled and hybrid HVAC systems.

5. Although water treatment practices, water desalination and groundwater acquisition need high initial costs and energy, water treatment is highly recommended as it focuses on reusing wastewater avoiding more exploitation of any potable water sources.

6. Natural water treatment systems are more preferable than conventional processes as they need less initial costs and consume less or no energy although they utilize greater areas of land, which can be comparatively cheap in such an arid region like Red Sea coasts.

7. Graywater, or treated wastewater, should replace potable water in all functions that do not need water with high quality.

8. Dual plumbing systems should be implemented in resorts to provide an applicable use of graywater for toilets and urinals flushing, washing phases in laundries and internal cooling cycles in HVAC systems.

9. Landscape irrigation systems should make a full use of graywater instead of potable water sources using drip irrigation or shallow trench systems.

10. Excess graywater can recharge groundwater aquifers for the possibility of reusing it during dry seasons. This process can be achieved using surface spreading, Vadose zone injection or direct injection.

Chapter five: Comparative analytical methodology for water consumption during operation phase

5.1. Calculation method for resort water consumption during operation phase
5.2. Comparative analytical field study for water consumption
5.3. Architectural decision matrix for selecting water efficient techniques in eco-resorts

5.1. Calculation method for resort water consumption during operation phase

Potable water is a scarce and valuable resource along the Red Sea coast. Most Red Sea resorts produce their own desalinated water through Reverse Osmosis (RO) or have it piped in from a nearby desalination plant, and a small number are supplied with water from tanker trucks and pay a premium price for this service. Depending on a property's location and the source of water it uses, the cost of water generally ranges from 5 to 20 EGP/m^3. Considering that an average 100-room resort can consume up to 4000 m^3 of water per month, water is one of the major expenditures in Red Sea resorts. [37]

Building type	Sinks	Dishwasher	Ice machine	Total kitchen	Basin	Toilet / Urinal	Restroom	Tot. bathroom (excl. showers)	Shower	Laundry	Cleaning	Cooling tower	Irrigation	Pool	Other	Losses
House	5%	6%		11%		31%		31%	37%	13%	4%		4%			0%
Supermarket				0%			7%	7%			14%	60%	5%		14%	0%
Sit-down restaurant	35%	22%	8%	65%			10%	10%				20%	5%			0%
Fast food restaurant	42%	6%	12%	60%			11%	11%				24%	5%			0%
Hotel / Resort				16%	3%	23%		26%	23%	15%	5%	10%	3%	2%		0%
Motel				18%	4%	25%		29%	26%	17%	5%		3%	2%		0%
Education primary				1%			61%	61%					36%	2%		0%
Education secondary				1%	4%	36%		40%			3%		53%	3%		0%
Education university				2%			66%	66%				10%	11%	1%	10%	0%
Commercial office				2%			50%	50%				40%	1%		7%	0%
Hospital / Convalescent home				8%			40%	40%		10%		13%	5%		24%	0%

Table 24 Breakdown of water end use for public building types
(Source Department of Natural Resources, Mines and Water, 2006)

Table 24 shows that bathrooms are the largest water-consumer in the majority of building types. Kitchens come in the second rank.

[37] (TDA), T. U. (2003). Environmental Management Guidelines for Coastal Hotels and Resorts - A Practical Approach to Cost Effective Environmental Management. In *Volume 1: Environmental Management Assessment.* Giza: The Egyptian Tourism Development Authority (TDA).

Thus, economic concerns alone should be sufficient to drive any Red Sea resort to carefully monitor and guard its use of water. However, this is generally not the case. Water efficiency is often overlooked, and even basic and well-recognized water conservation measures (such as the generalized use or low-flow showerheads) are seldom implemented. This oversight fosters excessive water consumption, which raises a property's operating costs, reduces its profitability, and needlessly increases its impact on the environment.

5.1.1. Water use indices

Given the wide differences in size, features, occupancy, age and class that exist among Red Sea resorts, total water consumption figures (expressed in m^3/month or m^3/year) cannot be used to compare their relative water efficiency or performance. Instead, the yardstick that is generally used to gauge a property's water consumption is the volume of water that it consumes per guest per day (or per guest night). This figure is commonly known as the resort's "water use index". [37]

Area / Type of activity	Water use		Wastewater generation	
Guestrooms	9%	●●●	10%	●●●
Lobby & Front-of-House areas	3%	●	3%	●
Public bathrooms	6%	●●	7%	●●
Restaurants	3%	●	3%	●
Bars	6%	●●	7%	●●
Offices	0%		0%	
Shops	0%		0%	
Kitchens	9%	●●●	10%	●●●
Stewarding operations	9%	●●●	10%	●●●
Housekeeping operations	3%	●	3%	●
Laundry	9%	●●●	10%	●●●
Stores	0%		0%	
Staff housing	9%	●●●	10%	●●●
Pool	9%	●●●	7%	●●
Beach	3%	●	0%	
Water sports	3%	●	0%	
Landscape	9%	●●●	0%	
Maintenance operations	3%	●	3%	●
Electricity generation plant	0%		0%	
Boiler room	3%	●	3%	●
Desalination plant	3%	●	10%	●●●
Wastewater treatment plant	3%	●	0%	
	100%		100%	

Table 25 Relative importance of water aspects by hotel department **(TDA, 2003)**

Table 25 shows that the most water-consumers from hotel sectors are guestrooms, kitchens, stewarding operations, laundry, staff housing, swimming pools and landscape.

A consumption index consists of the ratio of input to output or:

$$\text{Consumption index} = \text{Input} / \text{Output}$$

In order to provide an accurate representation of the overall water efficiency of a resort, this index is usually calculated based on the amount of water consumed in guestrooms as well as in all other resort areas, such as kitchens, bars, laundry, public areas, staff areas, grounds and pools. Although this appendix can be calculated over any time frame, it is generally used to track a property's water use performance from month to month, and year to year, as shown in the following formulas:

Monthly water use index =

$$\frac{\text{Volume of water consumed by the resort during month XX}}{\text{Occupancy during month XX}}$$

Annual water use index =

$$\frac{\text{Volume of water consumed by the resort during year YY}}{\text{Occupancy during year YY}}$$

Whenever possible, the consumption indices calculated for the property should be compared with acknowledged benchmarks or with indices obtained at other comparable properties. This comparison allows one to:

- Define the property's normal consumption patterns and track long-term trends in the consumption of inputs.
- Gauge the overall efficiency of the property and estimate how much its performance could, or should, improve.
- Uncover odd or unreasonable consumption patterns that result from inefficiencies or problems with the manner in which a specific input is used.
- Identify any unusual shifts in consumption that may indicate equipment problems (e.g., water leaks) or operational problems.
- Enable the team to evaluate the progress of future conservation and environmental efforts.

A. Monthly Water Use Index

The monthly index is a relatively volatile indicator. In Red Sea resorts, which have high base loads, it generally rises during times of low occupancy and drops during times of high occupancy, and can easily vary by ± 30% from one month to the next due to changes in weather, irrigation needs or occupancy rates.[37] This index is used to monitor a property's short-term water use patterns, and identify and investigate unusual shifts in consumption that cannot be attributed to irrigation practices, changes in occupancy, or other factors.

Although the monthly water use index (i.e., the water use per guest per day) is expected to fluctuate with time, large variations in response to changes in occupancy generally indicate that the amount of water guests actually consume is small compared to the resort's water base load. The water base load consists of all the water consumed in activities that are not directly related to the guests, such as irrigation with domestic water, evaporation losses from pools, leaks in water supply lines and plumbing fixtures, and water consumed in staff housing.

A good example of excessive variations in a property's water use index is shown in Figure 76, in which a 70% drop in occupancy from November to December triggered a 120% rise in its water use index. [37]

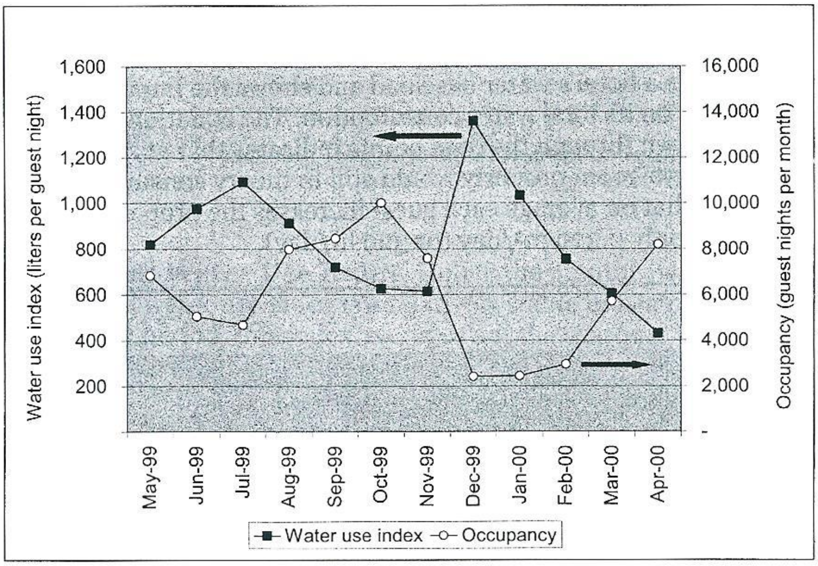


Figure 76 Monthly occupancy and water use index of a 240-room Red Sea resort **(TDA, 2003)**

The water use index graph of an ideal water-efficient resort, shown in Figure 77, would have relatively low and constant monthly water use index figures, regardless of occupancy.

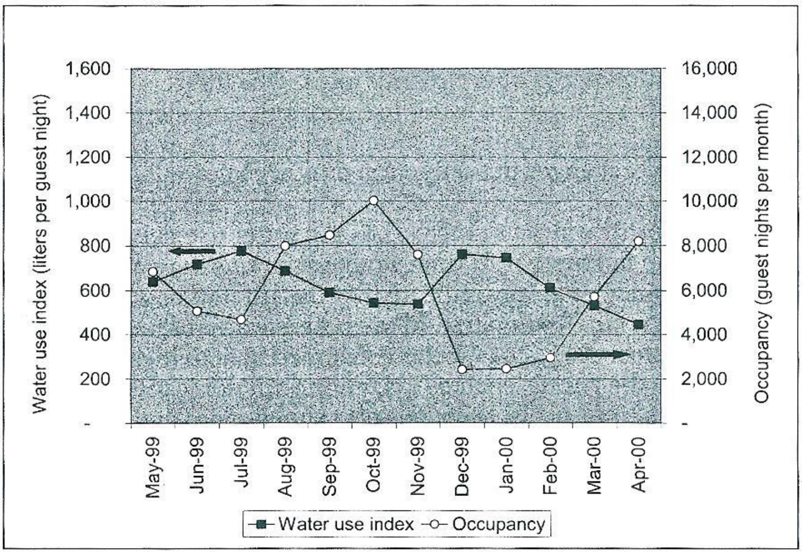


Figure 77 Monthly occupancy and "idealized" water use index of the Red Sea resort shown in figure above **(TDA, 2003)**

Figure 78 depicts a resort's water base load and shows the impact of individual guests on its total water consumption. The equation of the "best-fit line" drawn through the data points indicates that at zero occupancy, this 150-room property would still in theory consume 4503 m^3/month, and that on average each guest increases the property's water consumption by only 0.329 m^3/day (or 329 L/day).

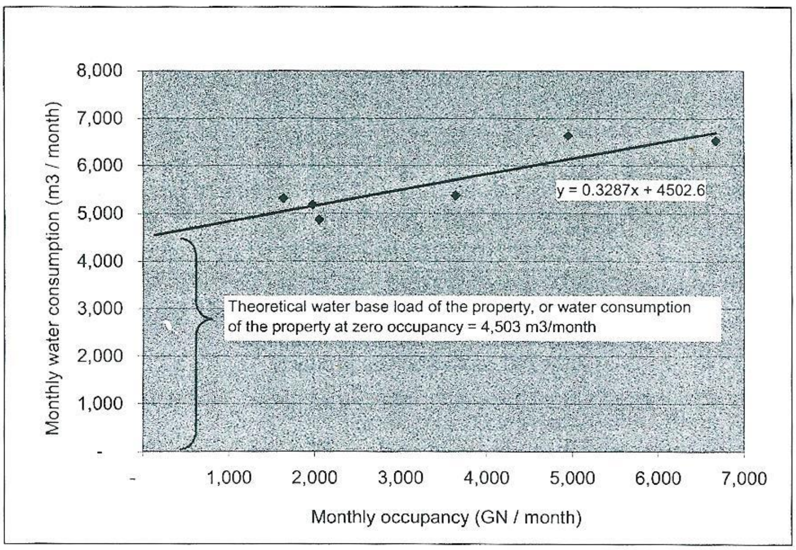


Figure 78 Monthly water consumption versus occupancy in a 150-room Red Sea resort **(TDA, 2003)**

As shown in Figure 79, the scatter graph of an ideal water-efficient resort would have the following characteristics:

- The best-fit line would cross the vertical axis relatively close to zero, thus indicating that the property has a small water base load.
- The best-fit line would be relatively flat (small slope), indicating that each guest uses, or causes the property to use, only a moderate amount of water.

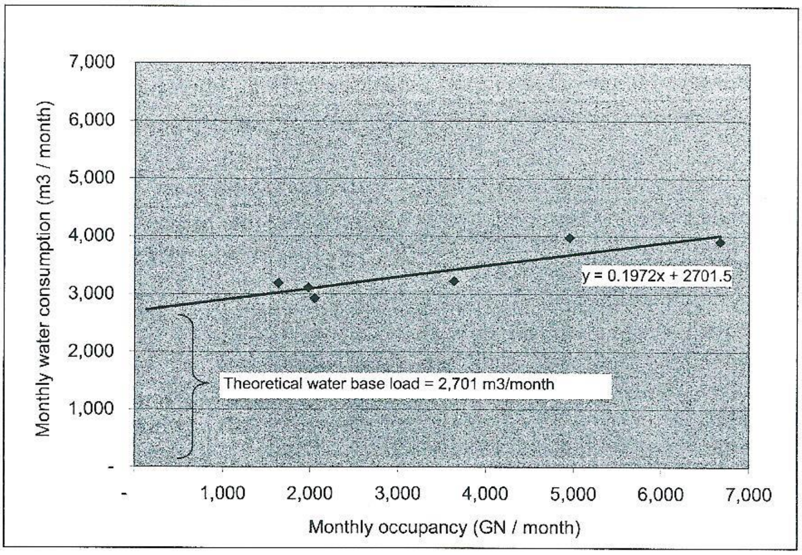


Figure 79 “Idealized” monthly water consumption versus occupancy in a 150-room Red Sea resort **(TDA, 2003)**

B. Annual Water Use Index

Unlike the monthly water use index, the annual water use index is a relatively stable indicator. By covering a 12-month period, this index averages out the seasonal variations in weather, occupancy and irrigation practices, and thus provides a better indication of the resort’s average performance. The annual water use index of a resort with stable operations and good maintenance practices does not generally vary by more than 20% from one year to the next.[37] This index is generally used to track the long-term water use patterns of a property and evaluate the overall impact of its water conservation efforts.

5.1.2. Water conservation in Red Sea resorts

Most water conservation in the hotel industry measures:

- Require no or little technical background to understand and implement.
- Can be implemented rabidly and with little labor.
- Can be sustained with only simple maintenance operations.
- Require modest investments, which generally range from LE 5 to 150 per room. [37]
- Offer short paybacks that generally range from 1 week to 6 months. [37]
- Can reduce the property's water consumption, water bills and sewerage costs.

Some main key parameters that, in addition to the hotel's number of rooms or number of guests, affect its required water supply capacity include:

- The climatic region of the hotel as shown in the table below.
- The star rating or classification of the hotel.
- The number of employees housed in the hotel or in adjacent staff quarters.

Water consumption (m3 per guest night)		Excellent	Satisfactory	High	Excessive
Luxury fully serviced hotels	Temperate	< 0.50	0.50 - 0.56	0.56 - 0.90	> 0.90
	Mediterranean	< 0.60	0.60 - 0.75	0.75 - 1.10	> 1.10
	Tropical	< 0.90	0.90 - 1.00	1.00 - 1.40	> 1.40
Mid -range fully serviced hotels	Temperate	< 0.35	0.35 - 0.41	0.41 - 0.75	> 0.75
	Mediterranean	< 0.45	0.45 - 0.60	0.60 - 0.95	> 0.95
	Tropical	< 0.70	0.70 - 0.80	0.80 - 1.20	> 1.20
Small / Budget fully serviced hotels	Temperate	< 0.20	0.20 - 0.21	0.21 - 0.31	> 0.31
	Mediterranean	< 0.22	0.22 - 0.25	0.25 - 0.38	> 0.38
	Tropical	< 0.29	0.29 - 0.30	0.30 - 0.46	> 0.46

Notes:
Benchmark values may adjust over time
The water consumption is measured in m3 in the table above (1 m3 = 1,000 liters)

Table 26 Benchmark values for fresh water used in typical hotels **(WWf UK, 2005)**

Table 26 shows that water consumption in different hotel rates depends on the climatic conditions of the hotels specially both temperature and humidity.

The required water supply capacity should be increased by 0.15 – 0.2 m^3/day for each employee that is housed in a hotel. [37]

The Egyptian Tourism Development Authority (TDA) set a proposed design consumption for tourism hotels by property classification as shown:

Hotel classification	Proposed design water consumption	Required water supply capacity of the hotel (m^3/day)
5-star	0.80 m^3/room.day	(number of rooms) x (1.0 m^3/room.day)
4-star	0.70 m^3/room.day	(number of rooms) x (0.7 m^3/room.day)
3-star	0.50 m^3/room.day	(number of rooms) x (0.6 m^3/room.day)

Table 27 TDA's proposed design consumption for tourism hotels **(TDA, 2003)**

Table 27 shows that there are differences in the proposed design water consumption for different hotel rates due to the variety of luxurious and recreational facilities available.

An example of the implementation of water conservation measures in Red Sea resorts shown in Figure 80, the retrofit consisted of installing flow restrictors in the hand-held showerheads to reduce their flow output to less than 9 L/min, replacing the existing inefficient faucet aerators with 5.6 L/min aerators, repairing toilet leaks, and adjusting the water level in the toilets' water tanks. It should be noted that these data were collected over two consecutive days, during which the same 25 guests occupied the same 14 rooms.

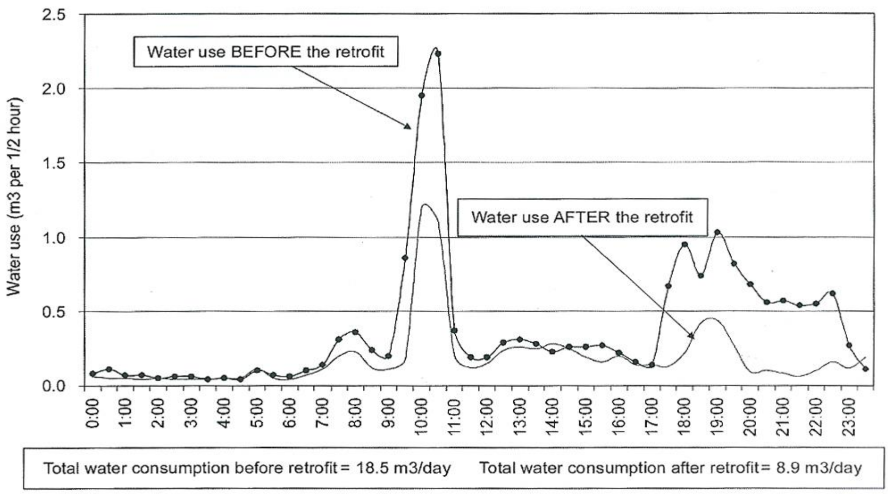


Figure 80 Water consumption in a guestroom block (14 rooms, 25 guests) before and after retrofitting the bathrooms with water-efficient fixtures **(TDA, 2003)**

5.1.3. Water consumption in resorts

The different water consumption figures, which are required for water usage calculations, can be obtained using the methodology discussed in Appendix B. Detailed water consumption for different fixtures and applications can be calculated using the same methodology.

Most modern resorts are constructed with en-suite facilities in each bedroom and these facilities are considered as constituting a domestic-type water use. In addition a resort may offer other services and facilities including restaurant facilities, leisure and laundry facilities. No allowances are included at this stage for water use in gymnasiums/health clubs.

The draft standards for resort employee water uses include toilet and urinal use, hand basin use and drinking water use. For resort guests the following uses are included; toilets, baths, showers and hand basins in rooms.

There are a large number of variables that must be considered when defining domestic water use in resorts. These variables include the facilities that the resort provides but also the number of guests and staff within the building and the number of 'casual' users of the resort facilities (i.e. those who are neither guests at the resort nor staff, but choose to use the resort for bar/restaurant facilities, conference facilities, etc). [38]

5.1.3.1. Draft standards for water consumption in resorts

Table 28 shows the draft water consumption standards that have been calculated using the methods and assumptions detailed in Appendix B. The standards have been broken down into 'modular' standards, to reflect the range of facilities that can be found in a resort.

	Baseline	Basic	Intermediate	Advanced
Room only	110	100	75	60
Room and staff	130	110	85	65
Room, staff and laundry	180	150	110	80
Room, staff, laundry and restaurant	240	200	150	105

Table 28 Draft water consumption values for new resorts (liters/room/day) **(Government, 2010)**

[38] Government, D. f. (2010). *Assessing the costs and benefits of improvements to the water efficiency of new non-household buildings - Final research report.* London: Crown.

5.2. Comparative analytical field study for water consumption

Red Sea region is considered a highly touristic zone that has great hospitality potentials. Various resorts, hotels and motels are stretched along the Red Sea region staring from Halayeb in the south to Ain Sukhna and Taba in the top northern gulfs of Suez and Aqaba.

Six resorts distributed in 3 touristic cities along the Red Sea coast (2 resorts for each city) are chosen as case studies in this thesis. These resorts are:

- Iberotel Coraya beach resort, Marsa Alam.
- Resta grand resort, Marsa Alam.
- Hilton Sharm Dreams resort, Sharm El-Sheikh.
- Movenpick Naama Bay resort, Sharm El-Sheikh.
- Hilton Taba & Nelson Village resort, Taba.
- Movenpick Taba resort, Taba.

Figure 81 Locations of case studies

5.2.1. Main functional sectors in case studies

The following figures show the main functional sectors in master plans of the selected case studies.

Figure 82 Main functional sectors in Iberotel Coraya beach resort, Marsa Alam, data from **(site survey done by the researcher)**

Figure 83 Main functional sectors in Resta grand resort, Marsa Alam, data from **(site survey done by the researcher)**

Figure 84 Main functional sectors in Hilton Sharm Dreams resort, Sharm El-Sheikh, data from **(site survey done by the researcher)**

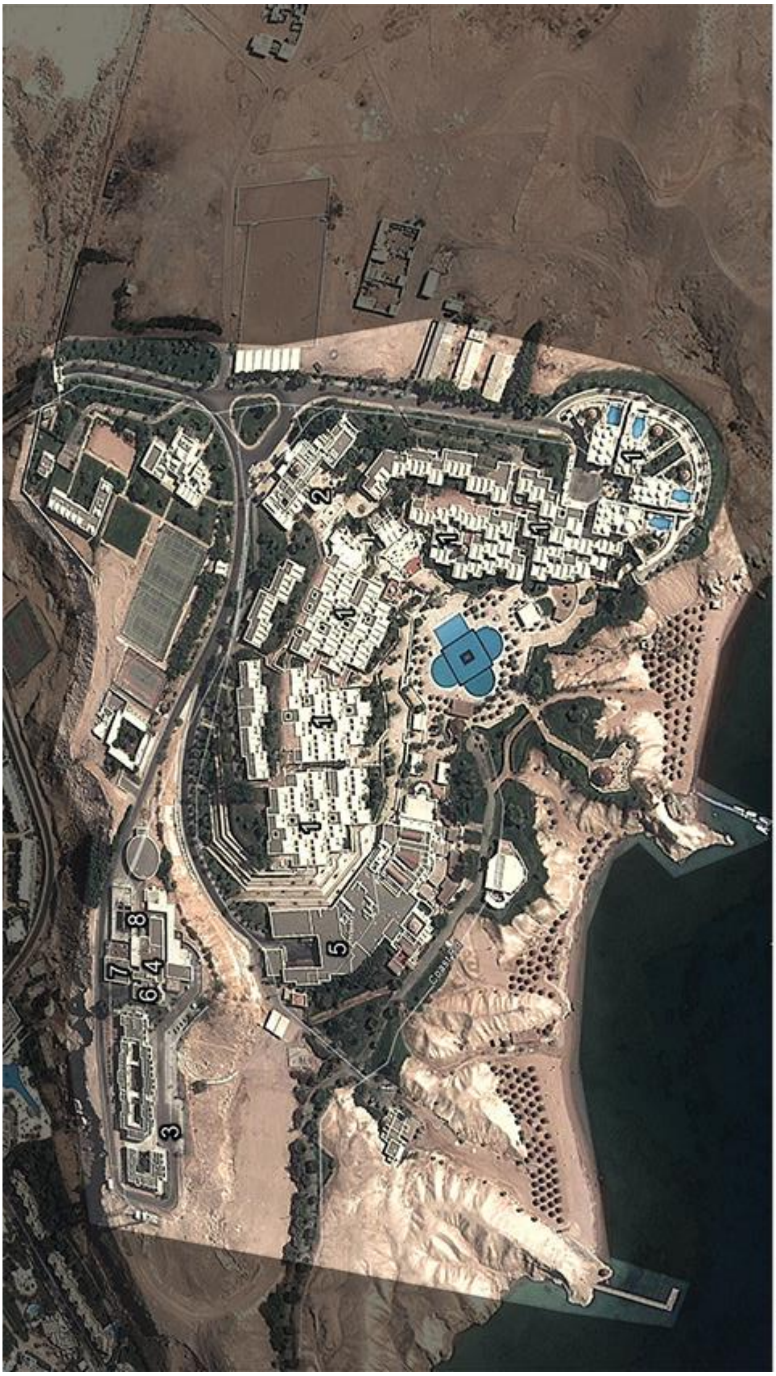


Figure 85 Main functional sectors in Movenpick Naama Bay resort, Sharm El-Sheikh, data from **(site survey done by the researcher)**

1 Guestrooms
2 Public spaces
3 Staff housing
4 Electro-Mechanical zones
5 Main kitchen
6 Laundry
7 Desalination plant
8 Sewage treatment plant

Figure 86 Main functional sectors in Hilton Taba & Nelson Village resort and Movenpick Taba resort, Taba, data from **(site survey done by the researcher)**

5.2.2. Selection criteria

The selection of case studies depends on the following similarities and differences:

A. Similarities

- Case studies are all 5-star rated resorts as this category is considered the most water-consuming among other lower categories. This is because of the high water demand for many luxurious leisure facilities included. Therefore, this category is critical for water consumption.

- Case studies are located in the western coasts of the Red Sea and the gulf of Aqaba which are two of the main Egyptian zones facing critical water shortage. However, these zones also are two of the main Egyptian priority zones for tourism development.

B. Differences

- Case studies have different sources for potable water.
- Case studies have different room capacities.
- Case studies are either old-operated, newly-operated or renovated.

Resort	Operation period	Operation case	Room capacity	Sources of potable water
Iberotel Coraya beach resort	Medium	As-built	364	Shared on-site desalination (5 resorts)
Resta grand resort	Low	As-built	400	Shared on-site desalination (2 resorts)
Hilton Sharm Dreams resort	Medium	As-built	394	Individual on-site desalination
Movenpick Naama Bay resort	High	Renovated	302	Individual on-site desalination
Hilton Taba resort	High	Renovated	400	Governmental desalination plant
Movenpick Taba resort	Medium	As-built	424	Governmental desalination plant

Table 29 Differences between case studies **(Data survey)**

5.2.2.1. Existing water consumption in case studies

Existing water consumption ratios by main sectors in case studies are presented in the following charts:

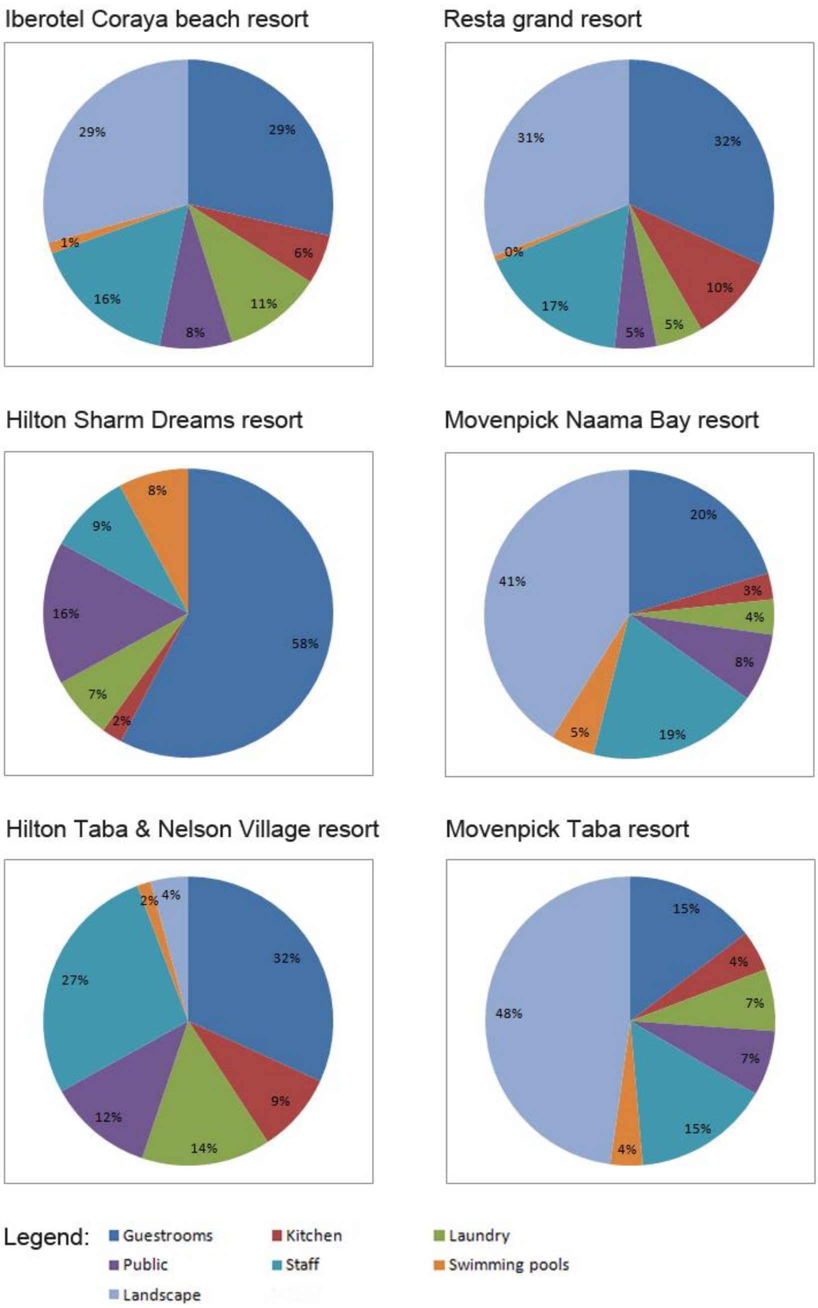


Figure 87 Existing water consumption ratios by main sectors in case studies
(Data survey in Appendix C)

Figure 87, the main water-consuming sectors in resorts can be orderly categorized, from higher to lower, as landscape, guestrooms, staff housing, public facilities, laundry, kitchen and swimming pools.

5.2.3. Comparative analysis

Case studies were comparatively analyzed by main sectors as shown below:

5.2.3.1. Guestrooms

The following is a full analysis of water consumption in guestrooms including all types of rooms and suites.

5.2.3.1.1. Currently used equipment

Currently used equipment in guestrooms are presented in the following table:

Used equipment		Marsa Alam				Sharm El-Sheikh				Taba			
		Coraya		Resta		Hilton		Movenpick		Hilton		Movenpick	
		Full	Partial	Full	Partial	Full	Partial	Full	Partial	Full	Partial	Full	Partial
Taps	Standard taps							●					
	Aerators / Flow restrictors	●		●		●				●		●	
	Low-flow taps												
Showers	Standard heads				●		●	●					
	Aerators / Flow restrictors	●			●		●			●		●	
	Low-flow												
Toilets	Single flush					●					●		
	Dual flush	●									●	●	
	Dual flush valve			●				●					
	Pressurized tanks												
	Composting toilets												

Table 30 Currently used equipment in guestrooms **(Data survey)**

Table 30 shows that all case studies use conventional to low-efficient water fixtures in guestrooms. Five resorts are low water-efficient for each item.

5.2.3.1.2. Water consumption scenarios

Results for monthly water consumption scenarios in guestrooms of case studies (calculated based on methodology in Appendix B) are presented in the following charts:

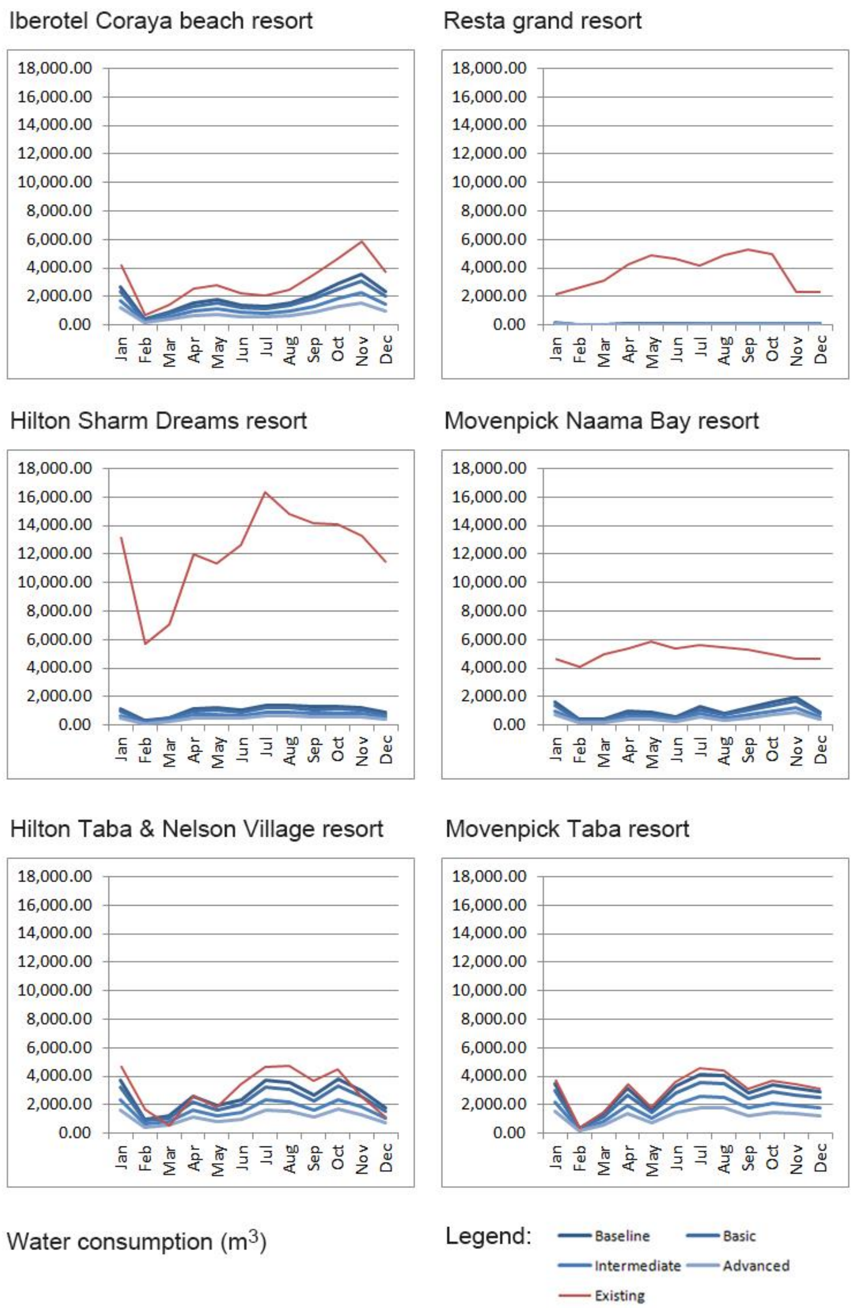


Figure 88 Charts for monthly water consumption scenarios in guestrooms of case studies **(Data survey in Appendix C)**

Figure 88 proves that case studies have conventional to low-efficient water usage in guestrooms. Although Resta grand resort guestrooms have low water-efficient fixtures, the graph shows that the existing water usage is very high compared with the four water-efficient scenarios. This problem can be due to user habits, plumbing malfunction or partial room refurbishment practices.

Hilton Sharm Dreams resort and Movenpick Naama Bay resort are proved to have high conventional water usage as their guestrooms almost have conventional water fixtures. Iberotel Coraya beach resort, Hilton Taba resort and Movenpick Taba resort are proved to have low-efficient water usage as their guestrooms almost have low water-efficient fixtures.

5.2.3.1.3. Further needed water-efficient alternatives

Further needed water-efficient alternatives in guestrooms of case studies are presented in the following table:

	Water-efficient equipment needed	Marsa Alam		Sharm El-Sheikh		Taba	
		Coraya	Resta	Hilton	Movenpick	Hilton	Movenpick
Taps	Aerators / Flow restrictors				●		
Taps	Low-flow taps	●	●	●	●	●	●
Taps	Automatic shutoff	●	●	●	●	●	●
Showers	Aerators / Flow restrictors		●	●	●		
Showers	Low-flow	●	●	●	●	●	●
Showers	Automatic shutoff	●	●	●	●	●	●
Toilets	Dual flush			●		●	
Toilets	Dual flush valve	●		●		●	●
Toilets	Pressurized tanks	●	●	●	●	●	●
Toilets	Vacuum toilets	●	●	●	●	●	●
Toilets	Composting toilets	●	●	●	●	●	●
Toilets	Incinerating toilets	●	●	●	●	●	●
Toilets	Treated graywater usage	●	●	●	●	●	●

Low water-efficient
Mid. water-efficient
High water-efficient
No potable water used

Table 31 Proposed water-efficient alternatives in guestrooms **(Researcher)**

Table 31 shows the categorization of all proposed water-efficient alternatives that can be applied to guestrooms of each case study. The blue tones in the background represent the four main categories for water-efficiency shown in the legend below the table.

5.2.3.2. Staff housing

The following is a full analysis of water consumption in staff housing including all staff (juniors and seniors) rooms, washrooms and cafeterias.

5.2.3.2.1. Currently used equipment

Currently used equipment in staff housing are presented in the following table:

Used equipment		Marsa Alam				Sharm El-Sheikh				Taba			
		Coraya		Resta		Hilton		Movenpick		Hilton		Movenpick	
		Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
Taps	Standard taps							●	●				
	Aerators / Flow restrictors	●	●	●	●	●	●			●	●	●	●
	Low-flow taps												
Showers	Standard heads							●	●				
	Aerators / Flow restrictors	●	●	●	●	●	●			●	●	●	●
	Low-flow												
Toilets	Single flush	●	●					●	●	●	●		
	Dual flush			●	●	●	●					●	●
	Dual flush valve												
Urinals	Standard urinals							●		●		●	
	Water-efficient	●		●		●							
	Low-flow												

Table 32 Currently used equipment in staff bathrooms **(Data survey)**

Table 32 shows that all case studies use conventional to low-efficient water fixtures in staff bathrooms. Movenpick Naama Bay resort is fully conventional. Resta grand resort and Hilton Sharm Dreams resort are fully low-efficient.

	Used equipment	Marsa Alam				Sharm El-Sheikh				Taba			
		Coraya		Resta		Hilton		Movenpick		Hilton		Movenpick	
		Full	Partial	Full	Partial	Full	Partial	Full	Partial	Full	Partial	Full	Partial
Dishwashers	Standard dishwashers		●		●		●	●			●	●	
	Efficient rinse nozzles		●								●		
	Use steam doors				●		●						
	Reuse rinse water												
	Install door switches												
Preparation / Pot and pan	Standard taps		●		●		●	●			●	●	
	Flow restrictors		●								●		
	Aerators				●		●						
	Infrared / Ultrasonic sensors												
Pre-rinse sprayers	Standard sprayers	●			●		●	●		●		●	
	High-efficient				●		●						
	Install automatic shutoff valve												
Ice machines	Water-cooled system	●		●		●		●		●		●	
	Air-cooled system												

Table 33 Currently used equipment in staff cafeterias **(Data survey)**

Table 33 shows that all case studies use conventional to mid-efficient water fixtures in staff cafeterias. Movenpick Naama Bay resort and Movenpick Taba resort are fully conventional. Iberotel Coraya beach resort and Hilton Taba resort are partially low-efficient. Resta grand resort and Hilton Sharm Dreams resort are partially mid-efficient.

5.2.3.2.2. Water consumption scenarios

Results for monthly water consumption scenarios in staff housing of case studies (calculated based on methodology in Appendix B) are presented in the following charts:

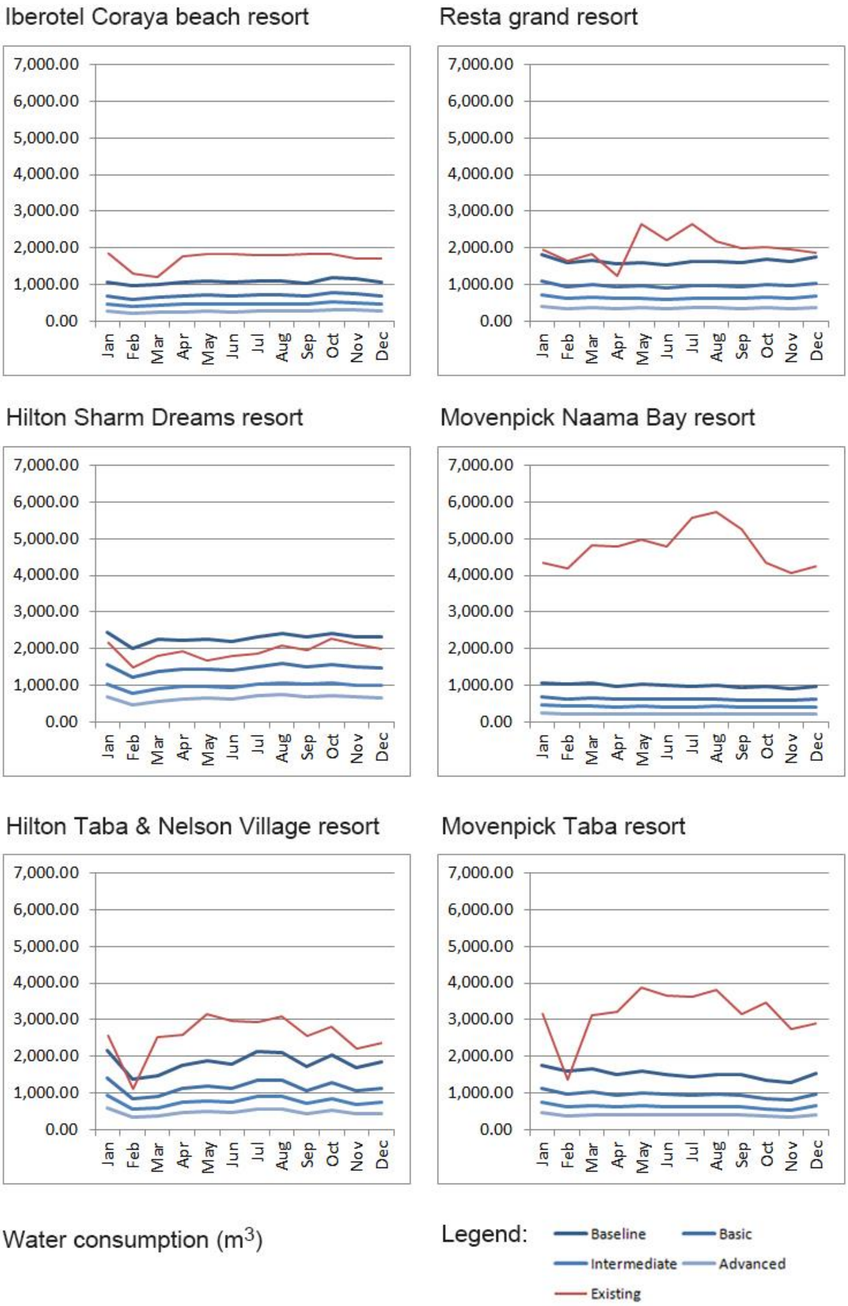


Figure 89 Charts for monthly water consumption scenarios in staff housing of case studies **(Data survey in Appendix C)**

Figure 89 proves that case studies have conventional to mid-efficient water usage in staff facilities. Although Resta grand resort, Iberotel Coraya beach resort and Hilton Taba resort staff facilities have low to medium water-efficient fixtures, the graph shows that the existing water usage is high compared with the four water-efficient scenarios. This problem can be due to user habits or plumbing malfunction. Movenpick Taba resort and Movenpick Naama Bay resort are proved to have high conventional water usage. Hilton Sharm Dreams resort is proved to have mid-efficient water usage.

5.2.3.2.3. Further needed water-efficient alternatives

Further needed water-efficient alternatives in staff housing of case studies are presented in the following table:

Water-efficient equipment needed		Marsa Alam		Sharm El-Sheikh		Taba	
		Coraya	Resta	Hilton	Movenpick	Hilton	Movenpick
Taps	Aerators / Flow restrictors				●		
Taps	Low-flow taps	●	●	●	●	●	●
Taps	Automatic shutoff	●	●	●	●	●	●
Showers	Aerators / Flow restrictors				●		
Showers	Low-flow	●	●	●	●	●	●
Showers	Automatic shutoff	●	●	●	●	●	●
Toilets	Dual flush	●			●	●	
Toilets	Dual flush valve	●	●	●	●	●	●
Toilets	Pressurized tanks	●	●	●	●	●	●
Toilets	Vacuum toilets	●	●	●	●	●	●
Toilets	Composting toilets	●	●	●	●	●	●
Toilets	Treated graywater usage	●	●	●	●	●	●
Urinals	Water-efficient				●	●	●
Urinals	Low-flow	●	●	●	●	●	●
Urinals	Smart flush system	●	●	●	●	●	●
Urinals	Waterless urinals	●	●	●	●	●	●
Urinals	Treated graywater usage	●	●	●	●	●	●

Low water-efficient
Mid. water-efficient
High water-efficient
No potable water used

Table 34 Proposed water-efficient alternatives in staff bathrooms **(Researcher)**

Table 34 shows the categorization of all proposed water-efficient alternatives that can be applied to staff bathrooms of each case study. The blue tones in the background represent the four main categories for water-efficiency shown in the legend below the table.

Water-efficient equipment needed		Marsa Alam		Sharm El-Sheikh		Taba	
		Coraya	Resta	Hilton	Movenpick	Hilton	Movenpick
Dishwashers	Install efficient rinse nozzles	●			●	●	●
	Reuse rinse water	●	●	●	●	●	●
	Install door switches	●	●	●	●	●	●
	Use steam doors to prevent evaporation	●	●	●	●	●	●
	Install Electric-eye sensors to operate only when dishes are present	●	●	●	●	●	●
	Highly-filtered graywater usage	●	●	●	●	●	●
Preparation / Pot and pan taps	Flow restrictors	●			●	●	●
	Aerators	●	●	●	●	●	●
	Infrared / Ultrasonic sensors	●	●	●	●	●	●
	Install pedal-operated taps for automatic shutoff	●	●	●	●	●	●
Pre-rinse sprayers	High-efficient	●			●	●	●
	Install automatic shutoff valve	●	●	●	●	●	●
	Treated graywater usage	●	●	●	●	●	●
Ice machine	Water-cooled system						
	Air-cooled system	●	●	●	●	●	●

- Low water-efficient
- Mid. water-efficient
- High water-efficient
- No potable water used

Table 35 Proposed water-efficient alternatives in staff cafeterias **(Researcher)**

Table 35 shows the categorization of all proposed water-efficient alternatives that can be applied to staff cafeterias of each case study. The blue tones in the background represent the four main categories for water-efficiency shown in the legend below the table.

5.2.3.3. Public utilities

The following is a full analysis of water consumption in public utilities including public bathrooms, outdoor showers and mechanical systems.

5.2.3.3.1. Currently used equipment

Currently used equipment in public utilities are presented in the following table:

Used equipment		Marsa Alam				Sharm El-Sheikh				Taba			
		Coraya		Resta		Hilton		Movenpick		Hilton		Movenpick	
		Full	Partial	Full	Partial	Full	Partial	Full	Partial	Full	Partial	Full	Partial
Taps	Standard taps							●					
	Aerators / Flow restrictors	●		●		●				●		●	
	Low-flow taps												
Showers	Standard heads		●			●		●			●		
	Aerators / Flow restrictors		●	●							●	●	
	Low-flow												
Toilets	Single flush						●				●		
	Dual flush	●					●		●		●	●	
	Dual flush valve			●					●				
	Pressurized tanks												
Urinals	Standard urinals				●				●				
	Water-efficient	●			●	●			●	●			
	Low-flow												
	Smart flush system											●	
	Waterless urinals												

Table 36 Currently used equipment in public bathrooms **(Data survey)**

Table 36 shows that all case studies use conventional to high-efficient water fixtures in public bathrooms. Resta grand resort, Hilton Sharm Dreams resort, Iberotel Coraya beach resort and Hilton Taba resort are conventional to low water-efficient. Movenpick Naama Bay resort is conventional to midium water-efficient. Movenpick Taba resort is low to high water-efficient.

	Used equipment	Marsa Alam				Sharm El-Sheikh				Taba			
		Coraya		Resta		Hilton		Movenpick		Hilton		Movenpick	
		Full	Partial	Full	Partial	Full	Partial	Full	Partial	Full	Partial	Full	Partial
HVAC	Standard systems	●		●		●		●		●		●	
HVAC	Evaporative cooling												
HVAC	Treated graywater / sea water usage										●		
Fire fighting	Standard sprinklers	●		●		●		●		●		●	
Fire fighting	Treated graywater in regular flushing of distribution system												

Table 37 Currently used equipment in mechanical systems **(Data survey)**

Table 37 shows that all case studies use conventional to high-efficient mechanical systems. Hilton Taba resort is conventional to high water-efficient. Other resorts are conventional.

5.2.3.3.2. Water consumption scenarios

Results for monthly water consumption scenarios in public utilities of case studies (calculated based on methodology in Appendix B) are presented in the following charts:

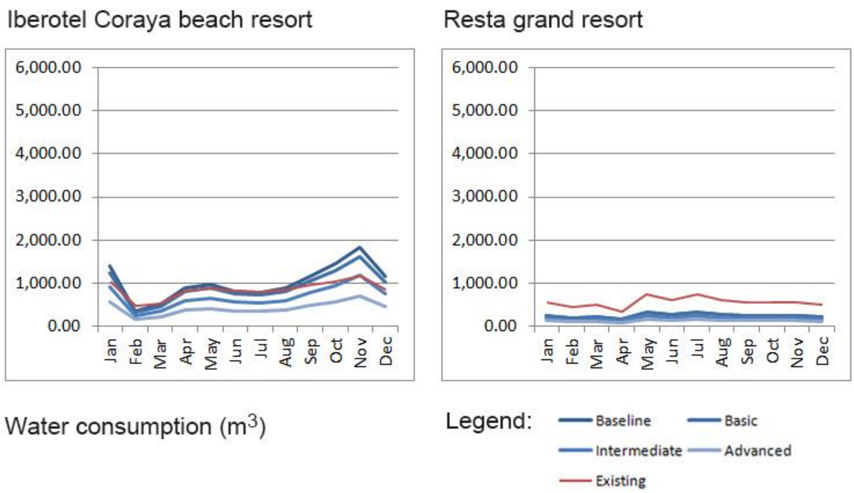


Figure 90 Charts for monthly water consumption scenarios in public utilities of case studies **(Data survey in Appendix C)**

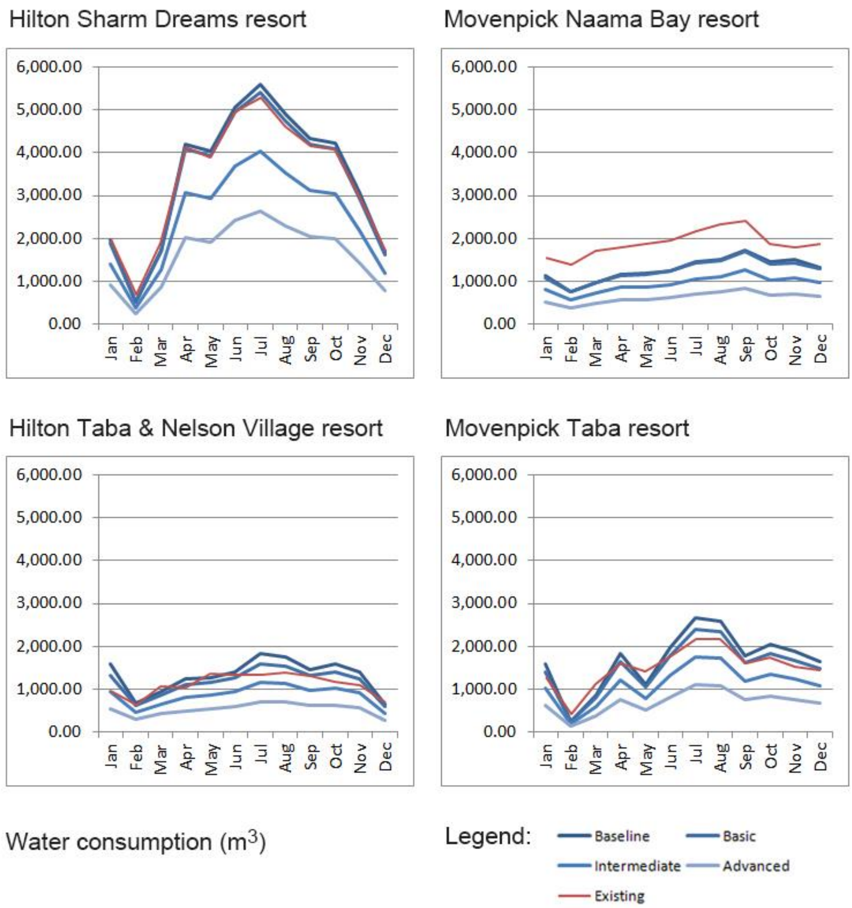


Figure 90 Charts for monthly water consumption scenarios in public utilities of case studies **(Data survey in Appendix C)** (continued)

Figure 90 proves that case studies have conventional to mid-efficient water usage in public sectors. Although Resta grand resort and Movenpick Naama Bay resort public sectors have conventional to medium water-efficient fixtures, the graph shows that the existing water usage is high compared with the four water-efficient scenarios. This problem can be due to user habits or plumbing malfunction for mechanical systems and fixtures in public bathrooms.

Hilton Sharm Dreams resort, Hilton Taba resort and Movenpick Taba resort are proved to have low to medium water-efficient usage. Iberotel Coraya beach resort is proved to have low to high water-efficient usage.

5.2.3.3.3. Further needed water-efficient alternatives

Further needed water-efficient alternatives in public utilities of case studies are presented in the following table:

Water-efficient equipment needed		Marsa Alam		Sharm El-Sheikh		Taba	
		Coraya	Resta	Hilton	Movenpick	Hilton	Movenpick
Taps	Aerators / Flow restrictors				●		
	Low-flow taps	●	●	●	●	●	●
	Automatic shutoff	●	●	●	●	●	●
Showers	Aerators / Flow restrictors	●		●	●	●	
	Low-flow	●	●	●	●	●	●
	Automatic shutoff	●	●	●	●	●	●
Toilets	Dual flush			●		●	
	Dual flush valve	●		●	●	●	●
	Pressurized tanks	●	●	●	●	●	●
	Vacuum toilets	●	●	●	●	●	●
	Composting toilets	●	●	●	●	●	●
	Incinerating toilets	●	●	●	●	●	●
	Graywater usage	●	●	●	●	●	●
Urinals	Water-efficient		●		●		
	Low-flow	●	●	●	●	●	
	Smart flush system	●	●	●	●	●	
	Waterless urinals	●	●	●	●	●	●
	Graywater usage	●	●	●	●	●	●

Low water-efficient
Mid. water-efficient
High water-efficient
No potable water used

Table 38 Proposed water-efficient alternatives in public bathrooms **(Researcher)**

Table 38 shows the categorization of all proposed water-efficient alternatives that can be applied to public bathrooms of each case study. The blue tones in the background represent the four main categories for water-efficiency shown in the legend below the table.

Water-efficient equipment needed		Marsa Alam		Sharm El-Sheikh		Taba	
		Coraya	Resta	Hilton	Movenpick	Hilton	Movenpick
HVAC	Evaporative cooling	●	●	●	●	●	●
	DMX system	●	●	●	●	●	●
	Water source geothermal system	●	●	●	●	●	●
	Liquid coolers	●	●	●	●	●	●
	Sea / Lake water cooling	●	●	●	●	●	●
	Air-cooled systems	●	●	●	●	●	●
	Hybrid systems	●	●	●	●	●	●
	In-ground heat source pump (IGHSP) system	●	●	●	●	●	●
Fire fighting	Treated graywater in regular flushing	●	●	●	●	●	●
	Highly-filtered graywater in sprinkler	●	●	●	●	●	●

Low water-efficient
Mid. water-efficient
High water-efficient
No potable water used

Table 39 Proposed water-efficient alternatives for mechanical systems **(Researcher)**

Table 39 shows the categorization of all proposed water-efficient alternatives that can be applied to mechanical systems of each case study. The blue tones in the background represent the four main categories for water-efficiency shown in the legend below the table.

5.2.3.4. Laundry

The following is a full analysis of water consumption in laundries.

5.2.3.4.1. Currently used equipment

Currently used equipment in laundries are presented in the following table:

Used equipment		Marsa Alam				Sharm El-Sheikh				Taba			
		Coraya		Resta		Hilton		Movenpick		Hilton		Movenpick	
		Full	Partial	Full	Partial	Full	Partial	Full	Partial	Full	Partial	Full	Partial
Washing machines	Standard machines	●			●		●	●			●		●
	High-efficient				●		●				●		●

Table 40 Currently used equipment in laundry **(Data survey)**

Table 40 shows that all case studies use conventional to low-efficient washing machines in laundries. Iberotel Coraya beach resort and Movenpick Naama Bay resort are conventional. Other resorts are conventional to low water-efficient.

5.2.3.4.2. Water consumption scenarios

Results for monthly water consumption scenarios in laundries of case studies (calculated based on methodology in Appendix B) are presented in the following charts:

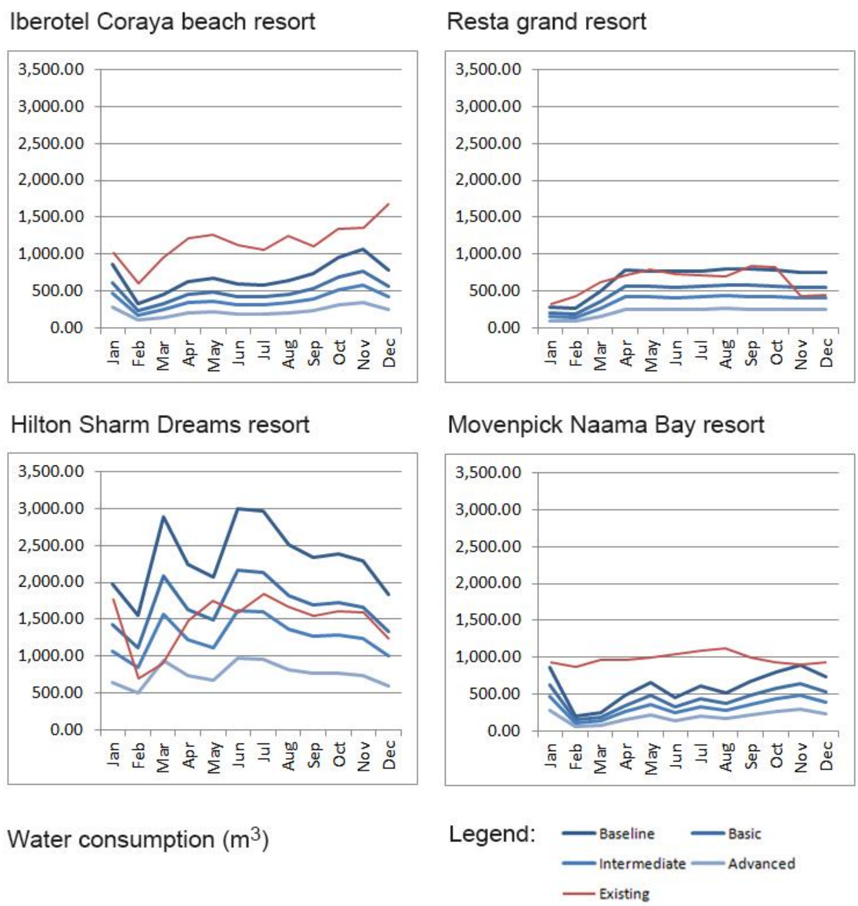


Figure 91 Charts for monthly water consumption scenarios in laundries of case studies **(Data survey in Appendix C)**

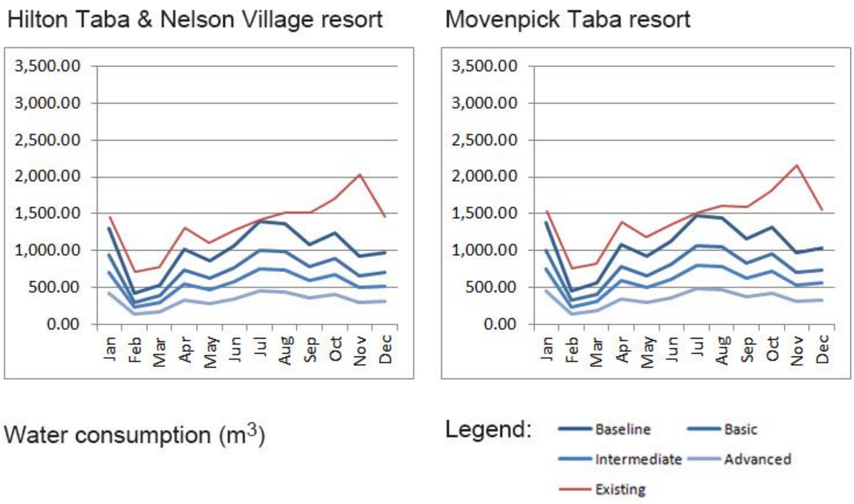


Figure 91 Charts for monthly water consumption scenarios in laundries of case studies **(Data survey in Appendix C)** (continued)

Figure 91 proves that case studies have conventional to high-efficient water usage in laundries. Iberotel Coraya beach resort and Movenpick Naama Bay resort are proved to have conventional water-efficient usage. Hilton Taba resort and Movenpick Taba resort are proved to have conventional to low water-efficient usage. Resta grand resort and Hilton Sharm Dreams resort are proved to have low to high water-efficient usage.

5.2.3.4.3. Further needed water-efficient alternatives

Further needed water-efficient alternatives in laundries of case studies are presented in the following table:

Water-efficient equipment needed		Marsa Alam		Sharm El-Sheikh		Taba	
		Coraya	Resta	Hilton	Movenpick	Hilton	Movenpick
Washing machines	High-efficient	●	●	●	●	●	●
	Ozone laundry system	●	●	●	●	●	●
	Highly-filtered graywater usage	●	●	●	●	●	●

Mid. water-efficient
High water-efficient
No potable water used

Table 41 Proposed water-efficient alternatives in laundries **(Researcher)**

Table 41 shows the categorization of all proposed water-efficient alternatives that can be applied to laundries of each case study. The blue tones in the background represent the four main categories for water-efficiency shown in the legend below the table.

5.2.3.5. Kitchen

The following is a full analysis of water consumption in main kitchens.

5.2.3.5.1. Currently used equipment

Currently used equipment in main kitchens are presented in the following table:

Used equipment		Marsa Alam				Sharm El-Sheikh				Taba			
		Coraya		Resta		Hilton		Movenpick		Hilton		Movenpick	
		Full	Partial	Full	Partial	Full	Partial	Full	Partial	Full	Partial	Full	Partial
Dishwashers	Standard dishwashers				●			●					
	Efficient rinse nozzles		●				●				●		●
	Use steam doors		●		●		●				●		●
Preparation / Pot and pan	Standard taps				●				●				
	Flow restrictors	●			●	●			●	●			●
	Pedal-operated taps												●
Pre-rinse sprayers	Standard sprayers				●			●					
	High-efficient	●			●	●				●		●	
Ice machines	Water-cooled system	●		●		●		●		●		●	
	Air-cooled system												

Table 42 Currently used equipment in main kitchens **(Data survey)**

Table 42 shows that all case studies use conventional to high-efficient water fixtures in main kitchens. Iberotel Coraya beach resort, Resta grand resort, Hilton Sharm Dreams resort and Hilton Taba resort are conventional to midium water-efficient. Movenpick Naama Bay resort is conventional to low water-efficient. Movenpick Taba resort is conventional to high water-efficient.

5.2.3.5.2. Water consumption scenarios

Results for monthly water consumption scenarios in main kitchens of case studies (calculated based on methodology in Appendix B) are presented in the following charts:

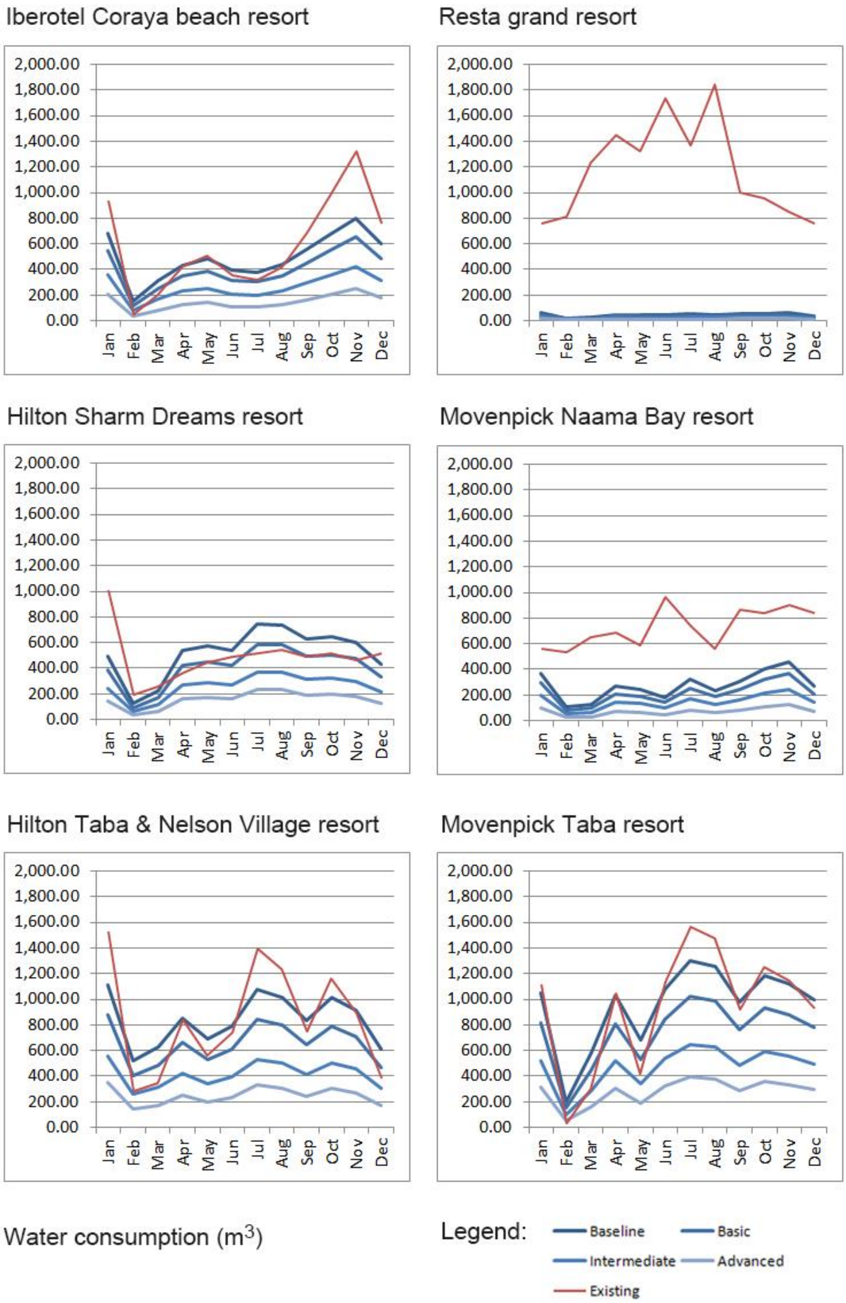


Figure 92 Charts for monthly water consumption scenarios in main kitchens of case studies **(Data survey in Appendix C)**

Figure 92 proves that case studies have conventional to high-efficient water usage in laundries. Although Resta grand resort and Movenpick Naama Bay resort main kitchens have conventional to medium water-efficient washing machines, the graph shows that the existing water usage is high compared with the four water-efficient scenarios. This problem can be due to user habits, plumbing malfunction or washing partial loads. Other resorts are proved to have conventional to high water-efficient usage.

5.2.3.5.3. Further needed water-efficient alternatives

Further needed water-efficient alternatives in main kitchens of case studies are presented in the following table:

Water-efficient equipment needed		Marsa Alam		Sharm El-Sheikh		Taba	
		Coraya	Resta	Hilton	Movenpick	Hilton	Movenpick
Dishwashers	Install efficient rinse nozzles		●		●		
	Reuse rinse water	●	●	●	●	●	●
	Install door switches	●	●	●	●	●	●
	Use steam doors to prevent evaporation	●	●	●	●	●	●
	Install Electric-eye sensors to operate only when dishes are present	●	●	●	●	●	●
	Highly-filtered graywater usage	●	●	●	●	●	●
Preparation / Pot and pan taps	Flow restrictors		●		●		
	Aerators	●	●	●	●	●	●
	Infrared / Ultrasonic sensors	●	●	●	●	●	●
	Install pedal-operated taps for automatic shutoff	●	●	●	●	●	●
Pre-rinse sprayers	High-efficient		●		●		
	Install automatic shutoff valve	●	●	●	●	●	●
	Treated graywater usage	●	●	●	●	●	●
Ice machine	Water-cooled system						
	Air-cooled system	●	●	●	●	●	●

Legend:
- Low water-efficient
- Mid. water-efficient
- High water-efficient
- No potable water used

Table 43 Proposed water-efficient alternatives in main kitchens **(Researcher)**

Table 43 shows the categorization of all proposed water-efficient alternatives that can be applied to main kitchens of each case study. The blue tones in the background represent the four main categories for water-efficiency shown in the legend below the table.

5.2.4. Yearly water savings achieved for each case study

Yearly water savings of different scenarios for water consumption in case studies (calculated based on methodology in Appendix B) are presented in the following charts:

5.2.4.1. Iberotel Coraya beach resort, Marsa Alam

Yearly water savings of different scenarios for water consumption in Iberotel Coraya beach resort by main indoor sectors are presented below:

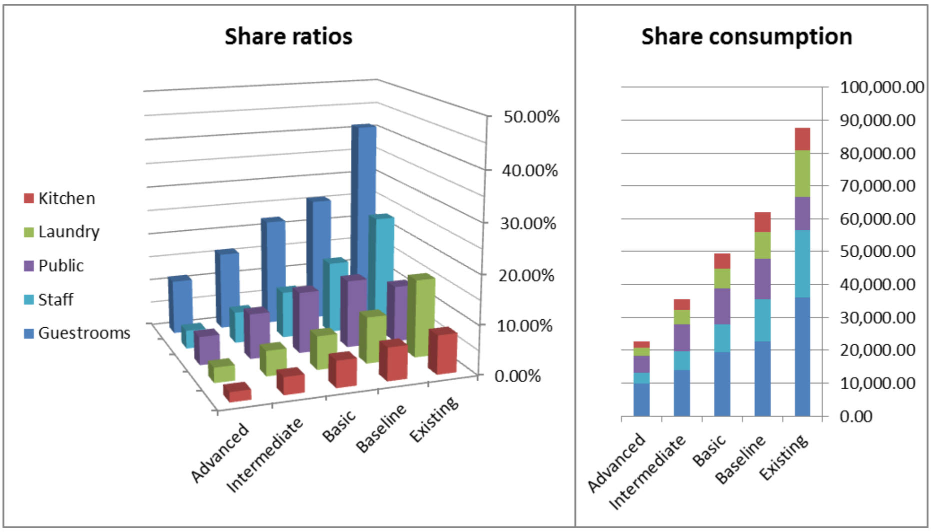


Figure 93 Share ratios and consumption for indoor sectors in Iberotel Coraya beach resort, Marsa Alam by different yearly water-efficient scenarios **(Researcher)**

In Figure 93, the yearly water consumption of main indoor sectors in the resort (detailed in Appendix C), for the different scenarios proposed, is presented proportionally (left chart) and numerically (right chart). The figure also summarizes the total water saving progress for the different water consumption scenarios as detailed below:

For guestrooms, the water consumption can be reduced from a share ratio of 41.01% from total existing indoor consumption to reach 27.30% in the advanced scenario, sharing 11.20% of the total consumption resulted.

For staff housing, the water consumption can be reduced from a share ratio of 23.44% from total existing indoor consumption to reach 16.07% in the advanced scenario, sharing 3.77% of the total consumption resulted.

For public spaces, the water consumption can be reduced from a share ratio of 11.67% from total existing indoor consumption to reach 49.65% in the advanced scenario, sharing 5.79% of the total consumption resulted.

For laundry, the water consumption can be reduced from a share ratio of 15.94% from total existing indoor consumption to reach 19.32% in the advanced scenario, sharing 3.08% of the total consumption resulted.

For kitchens, the water consumption can be reduced from a share ratio of 7.94% from total existing indoor consumption to reach 25.08% in the advanced scenario, sharing 1.99% of the total consumption resulted.

In Figure 94, the total yearly indoor water consumption in the resort (detailed in Appendix C), for the different scenarios proposed, is presented metrically (left chart) and financially (right chart).

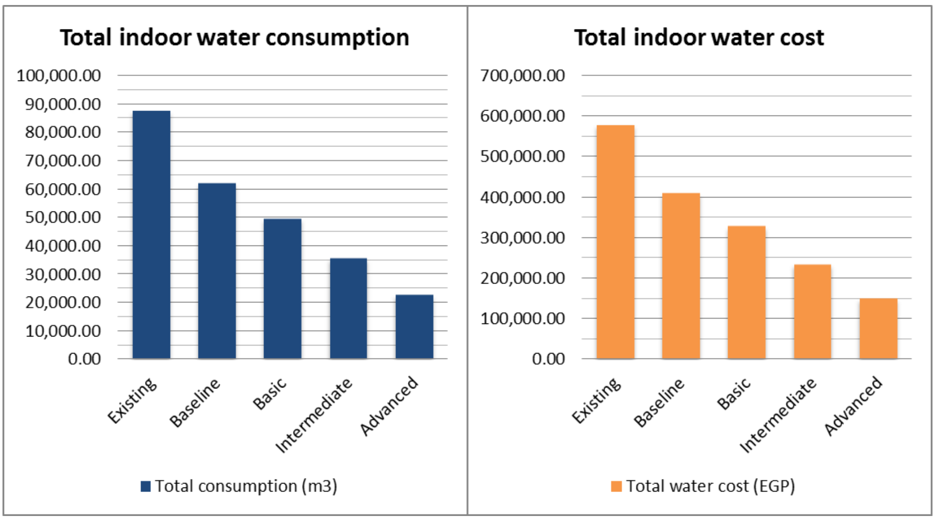


Figure 94 Yearly water consumption scenarios and their corresponding costs for Iberotel Coraya beach resort, Marsa Alam **(Researcher)**

Figure 94 shows that the total indoor water consumption, which is currently 87,737.78 m^3, can be reduced using different scenarios. The baseline scenario reduces the existing consumption to 61,992.50 m^3, which means reaching a saving ratio of 29.34%. The basic scenario reduces the existing consumption to 49,586.09 m^3, which means reaching a saving ratio of 43.48%. The intermediate scenario reduces the existing consumption to 35,454.60 m^3, which means reaching a saving ratio of 59.59%. Finally, the advanced scenario reduces the existing consumption to 22,660.71 m^3, which means reaching a saving ratio of 74.17%.

In the best water-efficient scenarios, the total water cost can be reduced from 579,069.33 EGP to 149,560.70 EGP, achieving a saving ratio of 74.17%.

5.2.4.2. Resta grand resort, Marsa Alam

Yearly water savings of different scenarios for water consumption in Resta grand resort by main indoor sectors are presented below:

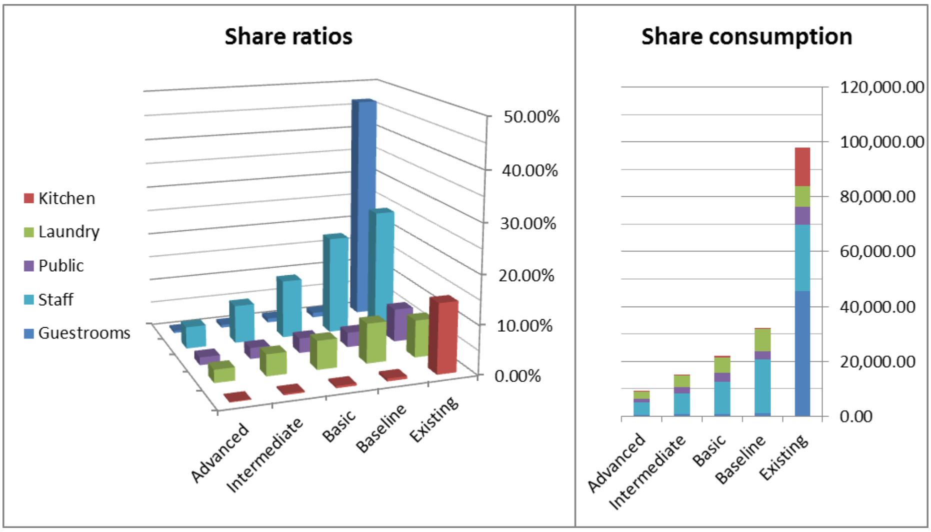


Figure 95 Share ratios and consumption for indoor sectors in Resta grand resort, Marsa Alam by different yearly water-efficient scenarios **(Researcher)**

In Figure 95, the yearly water consumption of main indoor sectors in the resort (detailed in Appendix C), for the different scenarios proposed, is presented proportionally (left chart) and numerically (right chart). The figure also summarizes the total water saving progress for the different water consumption scenarios as detailed below:

For guestrooms, the water consumption can be reduced from a share ratio of 46.45% from total existing indoor consumption to reach 0.93% in the advanced scenario, sharing 0.43% of the total consumption resulted.

For staff housing, the water consumption can be reduced from a share ratio of 24.68% from total existing indoor consumption to reach 18.27% in the advanced scenario, sharing 4.51% of the total consumption resulted.

For public spaces, the water consumption can be reduced from a share ratio of 6.83% from total existing indoor consumption to reach 23.30% in the advanced scenario, sharing 1.59% of the total consumption resulted.

For laundry, the water consumption can be reduced from a share ratio of 7.69% from total existing indoor consumption to reach 34.71% in the advanced scenario, sharing 2.67% of the total consumption resulted.

For kitchens, the water consumption can be reduced from a share ratio of 14.35% from total existing indoor consumption to reach 1.02% in the advanced scenario, sharing 0.15% of the total consumption resulted.

In Figure 96, the total yearly indoor water consumption in the resort (detailed in Appendix C), for the different scenarios proposed, is presented metrically (left chart) and financially (right chart).

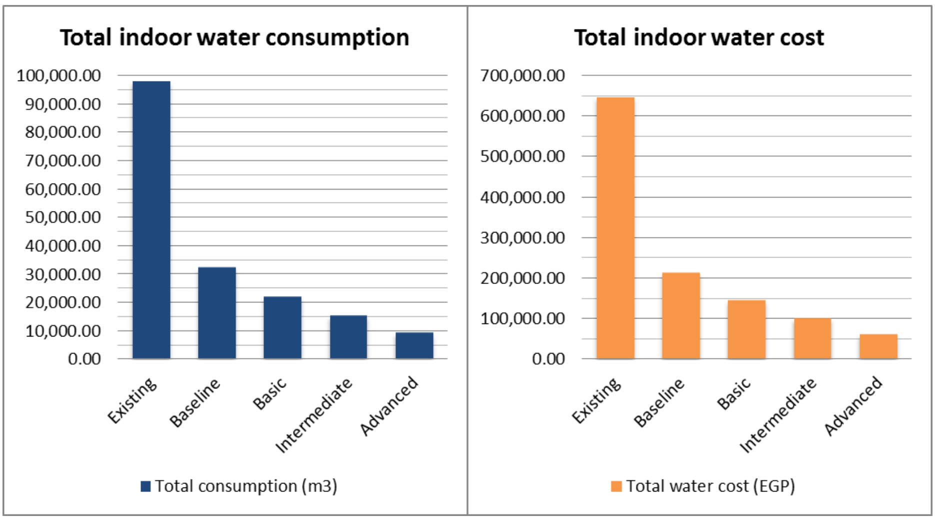


Figure 96 Yearly water consumption scenarios and their corresponding costs for Resta grand resort, Marsa Alam **(Researcher)**

Figure 96 shows that the total indoor water consumption, which is currently 98,096.54 m^3, can be reduced using different scenarios. The baseline scenario reduces the existing consumption to 32,275.15 m^3, which means reaching a saving ratio of 67.10%. The basic scenario reduces the existing consumption to 21,884.10 m^3, which means reaching a saving ratio of 77.69%. The intermediate scenario reduces the existing consumption to 15,211.20 m^3, which means reaching a saving ratio of 84.49%. Finally, the advanced scenario reduces the existing consumption to 9,170.28 m^3, which means reaching a saving ratio of 90.65%.

In the best water-efficient scenarios, the total water cost can be reduced from 647,437.17 EGP to 60,523.82 EGP, achieving a saving ratio of 90.65%.

5.2.4.3. Hilton Sharm Dreams resort, Sharm El-Sheikh

Yearly water savings of different scenarios for water consumption in Hilton Sharm Dreams resort by main indoor sectors are presented below:

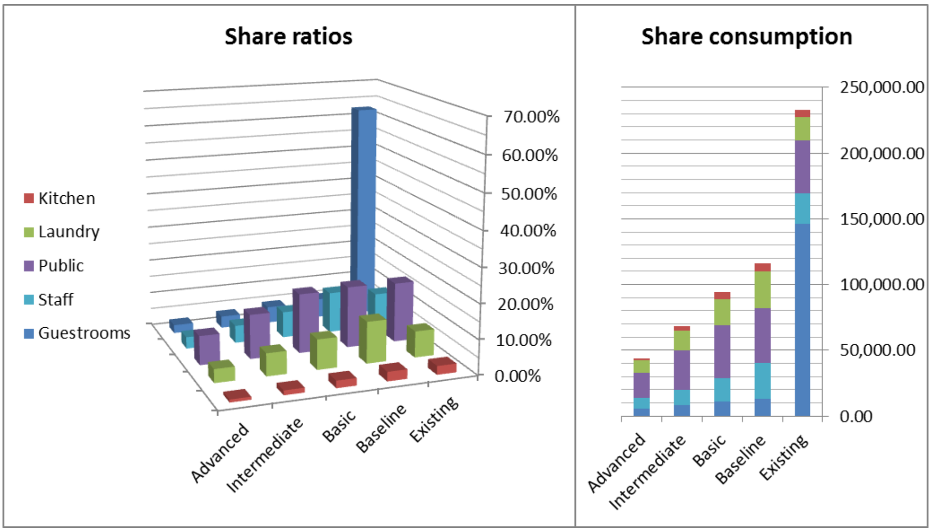


Figure 97 Share ratios and consumption for indoor sectors in Hilton Sharm Dreams resort, Sharm El-Sheikh by different yearly water-efficient scenarios **(Researcher)**

In Figure 97, the yearly water consumption of main indoor sectors in the resort (detailed in Appendix C), for the different scenarios proposed, is presented proportionally (left chart) and numerically (right chart). The figure also summarizes the total water saving progress for the different water consumption scenarios as detailed below:

For guestrooms, the water consumption can be reduced from a share ratio of 62.63% from total existing indoor consumption to reach 3.85% in the advanced scenario, sharing 2.41% of the total consumption resulted.

For staff housing, the water consumption can be reduced from a share ratio of 9.96% from total existing indoor consumption to reach 33.86% in the advanced scenario, sharing 3.37% of the total consumption resulted.

For public spaces, the water consumption can be reduced from a share ratio of 17.31% from total existing indoor consumption to reach 48.37% in the advanced scenario, sharing 8.38% of the total consumption resulted.

For laundry, the water consumption can be reduced from a share ratio of 7.60% from total existing indoor consumption to reach 51.49% in the advanced scenario, sharing 3.92% of the total consumption resulted.

For kitchens, the water consumption can be reduced from a share ratio of 2.49% from total existing indoor consumption to reach 32.63% in the advanced scenario, sharing 0.81% of the total consumption resulted.

In Figure 98, the total yearly indoor water consumption in the resort (detailed in Appendix C), for the different scenarios proposed, is presented metrically (left chart) and financially (right chart).

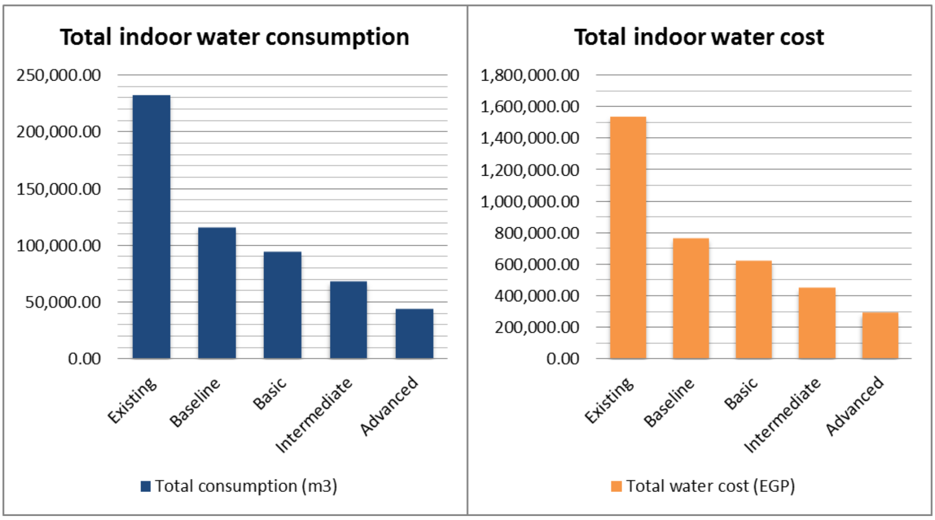


Figure 98 Yearly water consumption scenarios and their corresponding costs for Hilton Sharm Dreams resort, Sharm El-Sheikh **(Researcher)**

Figure 98 shows that the total indoor water consumption, which is currently 233,007.00 m^3, can be reduced using different scenarios. The baseline scenario reduces the existing consumption to 116,038.16 m^3, which means reaching a saving ratio of 50.20%. The basic scenario reduces the existing consumption to 93,960.04 m^3, which means reaching a saving ratio of 59.68%. The intermediate scenario reduces the existing consumption to 68,047.26 m^3, which means reaching a saving ratio of 70.80%. Finally, the advanced scenario reduces the existing consumption to 44,004.75 m^3, which means reaching a saving ratio of 81.11%.

In the best water-efficient scenarios, the total water cost can be reduced from 1,537,846.20 EGP to 290,431.33 EGP, achieving a saving ratio of 81.11%.

5.2.4.4. Movenpick Naama Bay resort, Sharm El-Sheikh

Yearly water savings of different scenarios for water consumption in Movenpick Naama Bay resort by main indoor sectors are presented below:

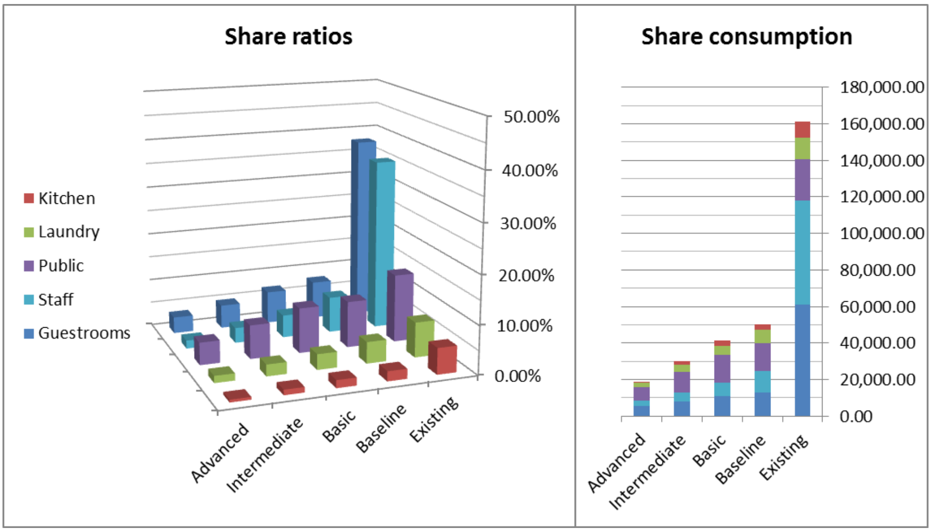


Figure 99 Share ratios and consumption for indoor sectors in Movenpick Naama Bay resort, Sharm El-Sheikh by different yearly water-efficient scenarios **(Researcher)**

In Figure 99, the yearly water consumption of main indoor sectors in the resort (detailed in Appendix C), for the different scenarios proposed, is presented proportionally (left chart) and numerically (right chart). The figure also summarizes the total water saving progress for the different water consumption scenarios as detailed below:

For guestrooms, the water consumption can be reduced from a share ratio of 37.81% from total existing indoor consumption to reach 9.01% in the advanced scenario, sharing 3.41% of the total consumption resulted.

For staff housing, the water consumption can be reduced from a share ratio of 35.44% from total existing indoor consumption to reach 4.75% in the advanced scenario, sharing 1.68% of the total consumption resulted.

For public spaces, the water consumption can be reduced from a share ratio of 14.07% from total existing indoor consumption to reach 32.94% in the advanced scenario, sharing 4.64% of the total consumption resulted.

For laundry, the water consumption can be reduced from a share ratio of 7.27% from total existing indoor consumption to reach 19.89% in the advanced scenario, sharing 1.45% of the total consumption resulted.

For kitchens, the water consumption can be reduced from a share ratio of 5.41% from total existing indoor consumption to reach 10.01% in the advanced scenario, sharing 0.54% of the total consumption resulted.

In Figure 100, the total yearly indoor water consumption in the resort (detailed in Appendix C), for the different scenarios proposed, is presented metrically (left chart) and financially (right chart).

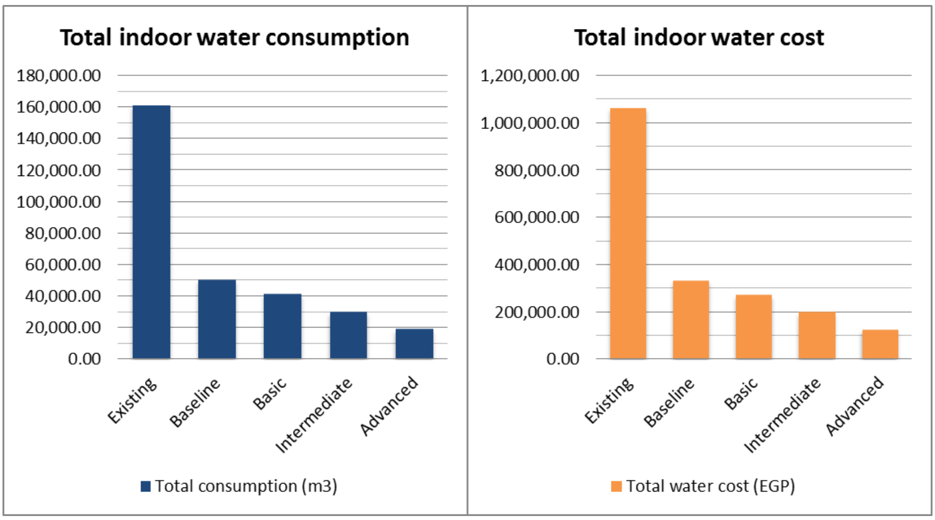


Figure 100 Yearly water consumption scenarios and their corresponding costs for Movenpick Naama Bay resort, Sharm El-Sheikh **(Researcher)**

Figure 100 shows that the total indoor water consumption, which is currently 161,155.00 m³, can be reduced using different scenarios. The baseline scenario reduces the existing consumption to 50,429.54 m³, which means reaching a saving ratio of 68.71%. The basic scenario reduces the existing consumption to 41,219.03 m³, which means reaching a saving ratio of 74.42%. The intermediate scenario reduces the existing consumption to 29,828.97 m³, which means reaching a saving ratio of 81.49%. Finally, the advanced scenario reduces the existing consumption to 18,875.37 m³, which means reaching a saving ratio of 88.29%.

In the best water-efficient scenarios, the total water cost can be reduced from 1,063,623.00 EGP to 124,577.43 EGP, achieving a saving ratio of 88.29%.

5.2.4.5. Hilton Taba & Nelson Village resort, Taba

Yearly water savings of different scenarios for water consumption in Hilton Taba & Nelson Village resort by main indoor sectors are presented below:

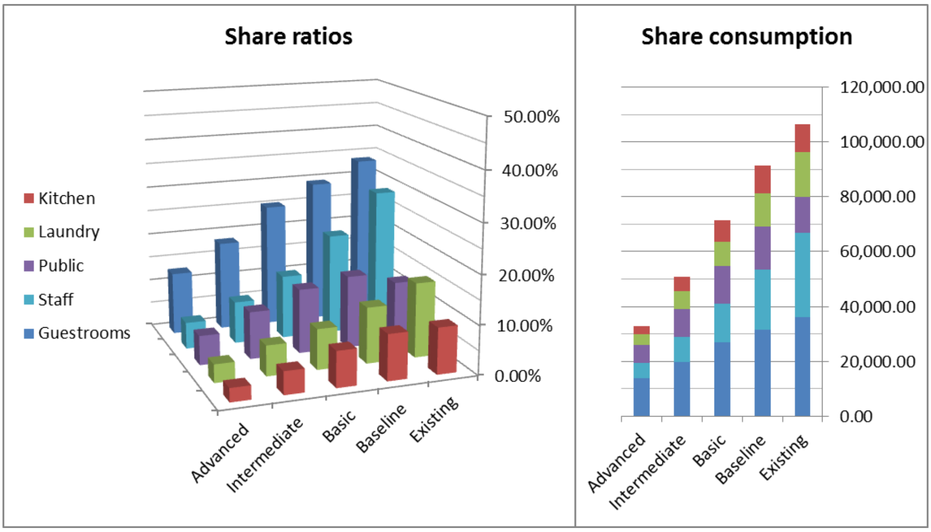


Figure 101 Share ratios and consumption for indoor sectors in Hilton Taba & Nelson Village resort, Taba by different yearly water-efficient scenarios **(Researcher)**

In Figure 101, the yearly water consumption of main indoor sectors in the resort (detailed in Appendix C), for the different scenarios proposed, is presented proportionally (left chart) and numerically (right chart). The figure also summarizes the total water saving progress for the different water consumption scenarios as detailed below:

For guestrooms, the water consumption can be reduced from a share ratio of 33.72% from total existing indoor consumption to reach 38.02% in the advanced scenario, sharing 12.82% of the total consumption resulted.

For staff housing, the water consumption can be reduced from a share ratio of 28.97% from total existing indoor consumption to reach 18.71% in the advanced scenario, sharing 5.42% of the total consumption resulted.

For public spaces, the water consumption can be reduced from a share ratio of 12.51% from total existing indoor consumption to reach 47.90% in the advanced scenario, sharing 5.99% of the total consumption resulted.

For laundry, the water consumption can be reduced from a share ratio of 15.31% from total existing indoor consumption to reach 24.37% in the advanced scenario, sharing 3.73% of the total consumption resulted.

For kitchens, the water consumption can be reduced from a share ratio of 9.50% from total existing indoor consumption to reach 29.37% in the advanced scenario, sharing 2.79% of the total consumption resulted.

In Figure 102, the total yearly indoor water consumption in the resort (detailed in Appendix C), for the different scenarios proposed, is presented metrically (left chart) and financially (right chart).

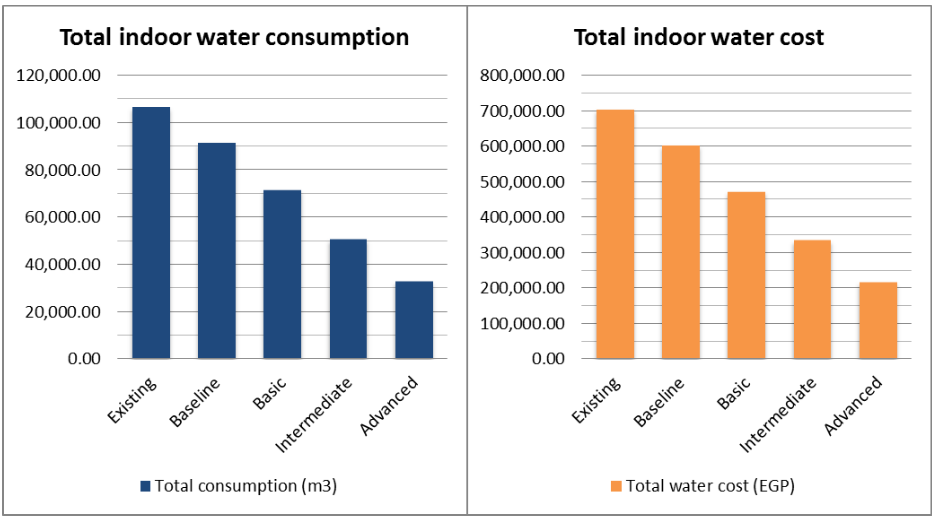


Figure 102 Yearly water consumption scenarios and their corresponding costs for Hilton Taba & Nelson Village resort, Taba **(Researcher)**

Figure 102 shows that the total indoor water consumption, which is currently 106,558.95 m^3, can be reduced using different scenarios. The baseline scenario reduces the existing consumption to 91,441.01 m^3, which means reaching a saving ratio of 14.19%. The basic scenario reduces the existing consumption to 71,567.50 m^3, which means reaching a saving ratio of 32.84%. The intermediate scenario reduces the existing consumption to 50,703.17 m^3, which means reaching a saving ratio of 52.42%. Finally, the advanced scenario reduces the existing consumption to 32,766.26 m^3, which means reaching a saving ratio of 69.25%.

In the best water-efficient scenarios, the total water cost can be reduced from 703,289.07 EGP to 216,257.28 EGP, achieving a saving ratio of 69.25%.

5.2.4.6. Movenpick Taba resort, Taba

Yearly water savings of different scenarios for water consumption in Movenpick Taba resort by main indoor sectors are presented below:

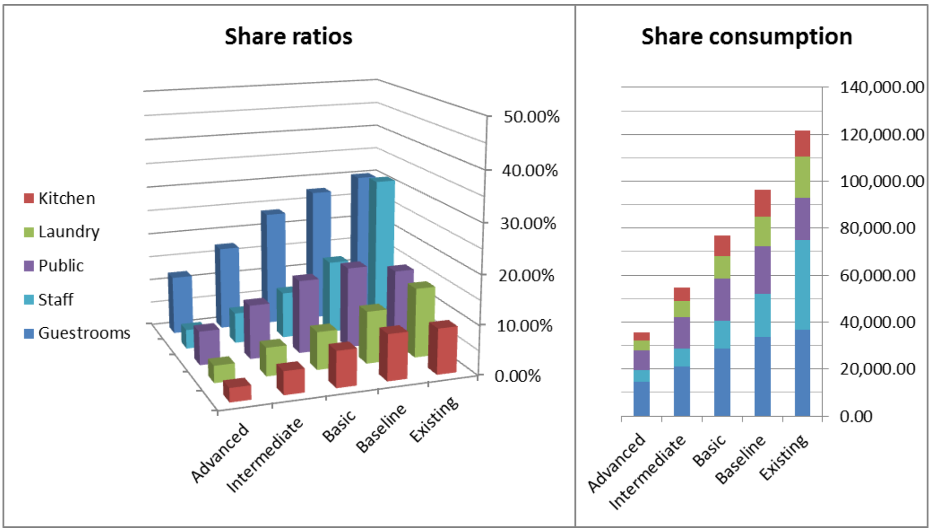


Figure 103 Share ratios and consumption for indoor sectors in Movenpick Taba resort, Taba by different yearly water-efficient scenarios **(Researcher)**

In Figure 103, the yearly water consumption of main indoor sectors in the resort (detailed in Appendix C), for the different scenarios proposed, is presented proportionally (left chart) and numerically (right chart). The figure also summarizes the total water saving progress for the different water consumption scenarios as detailed below:

For guestrooms, the water consumption can be reduced from a share ratio of 30.16% from total existing indoor consumption to reach 39.90% in the advanced scenario, sharing 12.03% of the total consumption resulted.

For staff housing, the water consumption can be reduced from a share ratio of 31.39% from total existing indoor consumption to reach 12.55% in the advanced scenario, sharing 3.94% of the total consumption resulted.

For public spaces, the water consumption can be reduced from a share ratio of 14.94% from total existing indoor consumption to reach 46.12% in the advanced scenario, sharing 6.89% of the total consumption resulted.

For laundry, the water consumption can be reduced from a share ratio of 14.21% from total existing indoor consumption to reach 24.37% in the advanced scenario, sharing 3.46% of the total consumption resulted.

For kitchens, the water consumption can be reduced from a share ratio of 9.30% from total existing indoor consumption to reach 30.00% in the advanced scenario, sharing 2.79% of the total consumption resulted.

In Figure 104, the total yearly indoor water consumption in the resort (detailed in Appendix C), for the different scenarios proposed, is presented metrically (left chart) and financially (right chart).

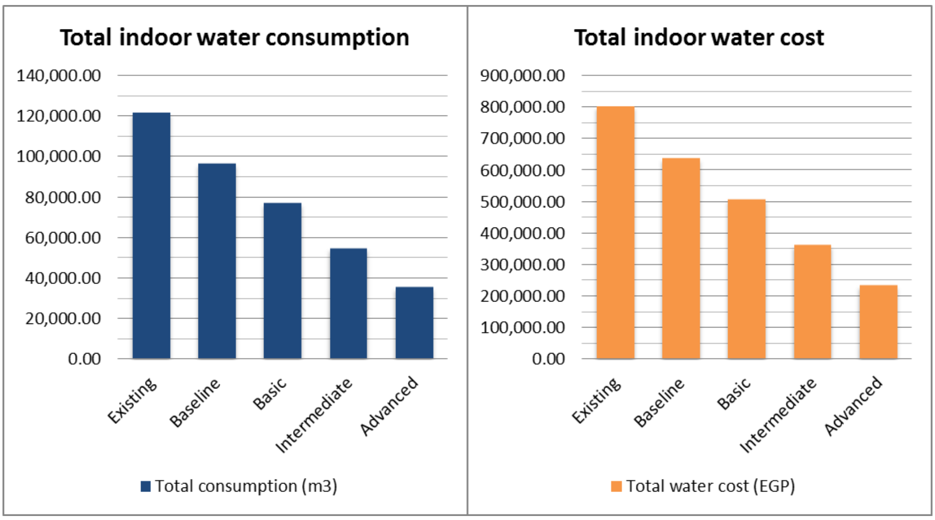


Figure 104 Yearly water consumption scenarios and their corresponding costs for Movenpick Taba resort, Taba **(Researcher)**

Figure 104 shows that the total indoor water consumption, which is currently 121,699.45 m^3, can be reduced using different scenarios. The baseline scenario reduces the existing consumption to 96,536.33 m^3, which means reaching a saving ratio of 20.68%. The basic scenario reduces the existing consumption to 77,014.91 m^3, which means reaching a saving ratio of 36.72%. The intermediate scenario reduces the existing consumption to 54,771.36 m^3, which means reaching a saving ratio of 54.99%. Finally, the advanced scenario reduces the existing consumption to 35,434.75 m^3, which means reaching a saving ratio of 70.88%.

In the best water-efficient scenarios, the total water cost can be reduced from 803,216.37 EGP to 233,869.33 EGP, achieving a saving ratio of 70.88%.

5.2.5. Overall yearly water savings achieved for each indoor sectors

Yearly water savings of different scenarios for each main indoor sector in case studies (detailed in Appendix C) are presented in the following charts:

5.2.5.1. Guestrooms

The following figure presents the yearly water saving ratios of different scenarios for guestrooms in case studies.

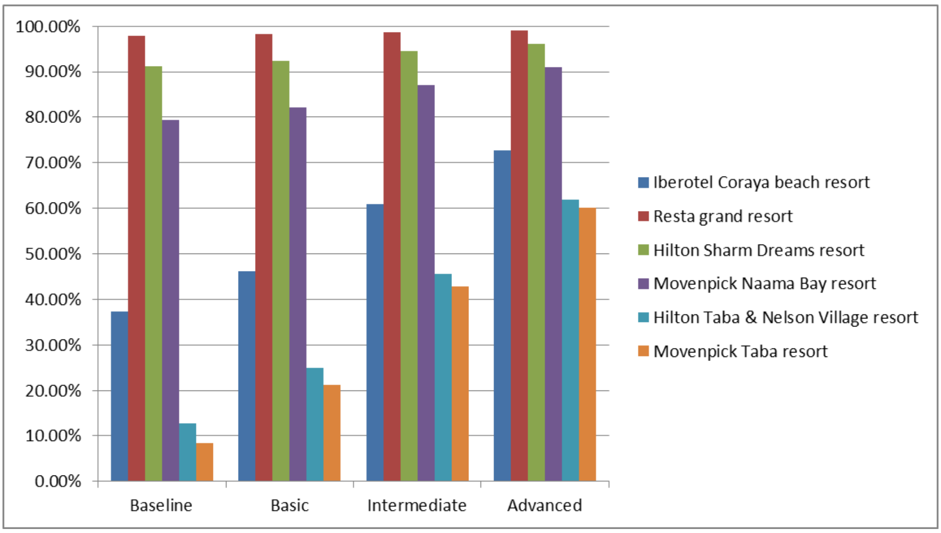


Figure 105 yearly water saving ratios of different scenarios for guestrooms in case studies **(Researcher)**

From Figure 105, the average water saving ratios can be concluded as followed:

By applying the baseline scenario to all case studies, low water saving ratios can be achieved. The average water saving ratio for baseline scenario in resorts can reach 54.44%.

By applying the basic scenario to all case studies, medium water saving ratios can be achieved. The average water saving ratio for basic scenario in resorts can reach 60.86%.

By applying the intermediate scenario to all case studies, high water saving ratios can be achieved. The average water saving ratio for intermediate scenario in resorts can reach 71.61%.

By applying the advanced scenario to all case studies, higher water saving ratios can be achieved. The average water saving ratio for advanced scenario in resorts can reach 80.16%.

5.2.5.2. Staff housing

The following figure presents the yearly water saving ratios of different scenarios for staff housing in case studies.

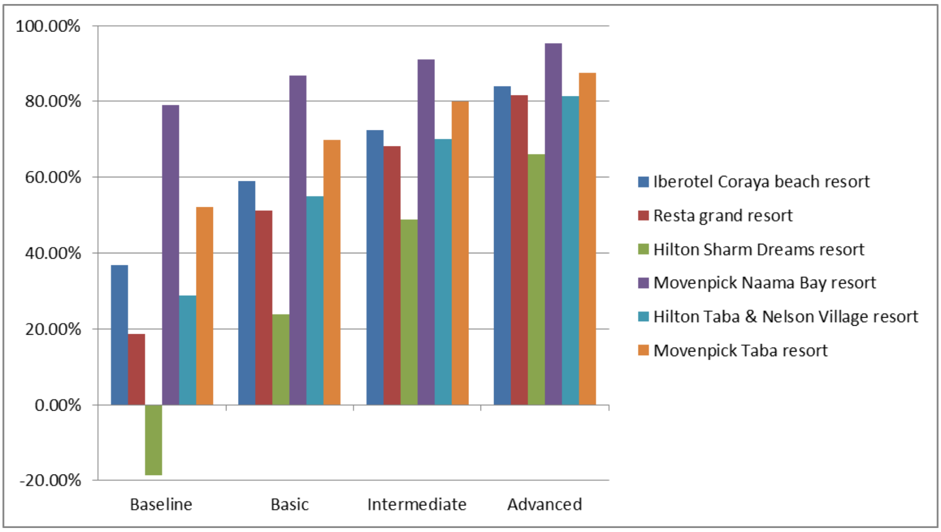


Figure 106 yearly water saving ratios of different scenarios for staff housing in case studies **(Researcher)**

From Figure 106, the average water saving ratios can be concluded as followed:

By applying the baseline scenario to all case studies, low water saving ratios can be achieved. The average water saving ratio for baseline scenario in resorts can reach 32.77%.

By applying the basic scenario to all case studies, medium water saving ratios can be achieved. The average water saving ratio for basic scenario in resorts can reach 57.62%.

By applying the intermediate scenario to all case studies, high water saving ratios can be achieved. The average water saving ratio for intermediate scenario in resorts can reach 71.79%.

By applying the advanced scenario to all case studies, higher water saving ratios can be achieved. The average water saving ratio for advanced scenario in resorts can reach 82.63%.

5.2.5.3. Public utilities

The following figure presents the yearly water saving ratios of different scenarios for public utilities in case studies.

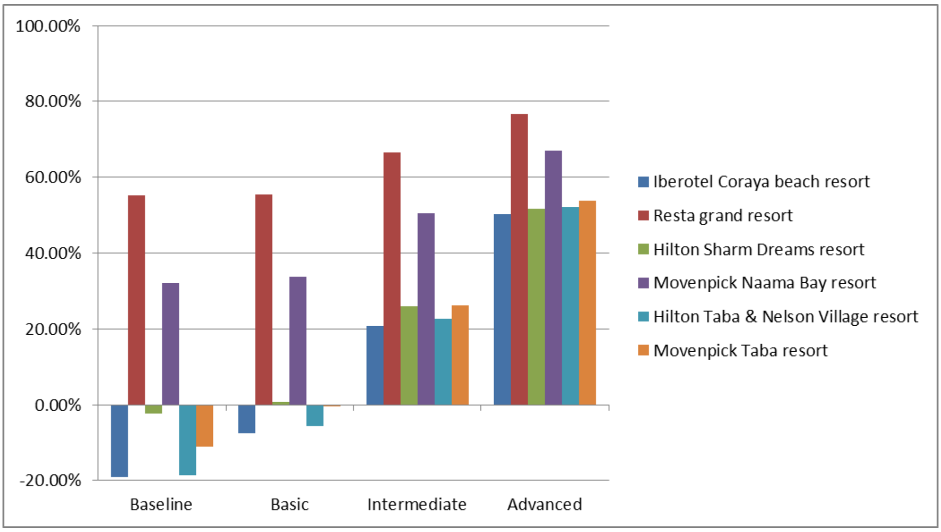


Figure 107 yearly water saving ratios of different scenarios for public spaces in case studies **(Researcher)**

From Figure 107, the average water saving ratios can be concluded as followed:

By applying the baseline scenario to all case studies, low water saving ratios can be achieved. The average water saving ratio for baseline scenario in resorts can reach 6.06%.

By applying the basic scenario to all case studies, medium water saving ratios can be achieved. The average water saving ratio for basic scenario in resorts can reach 12.70%.

By applying the intermediate scenario to all case studies, high water saving ratios can be achieved. The average water saving ratio for intermediate scenario in resorts can reach 35.41%.

By applying the advanced scenario to all case studies, higher water saving ratios can be achieved. The average water saving ratio for advanced scenario in resorts can reach 58.62%.

5.2.5.4. Laundry

The following figure presents the yearly water saving ratios of different scenarios for laundries in case studies.

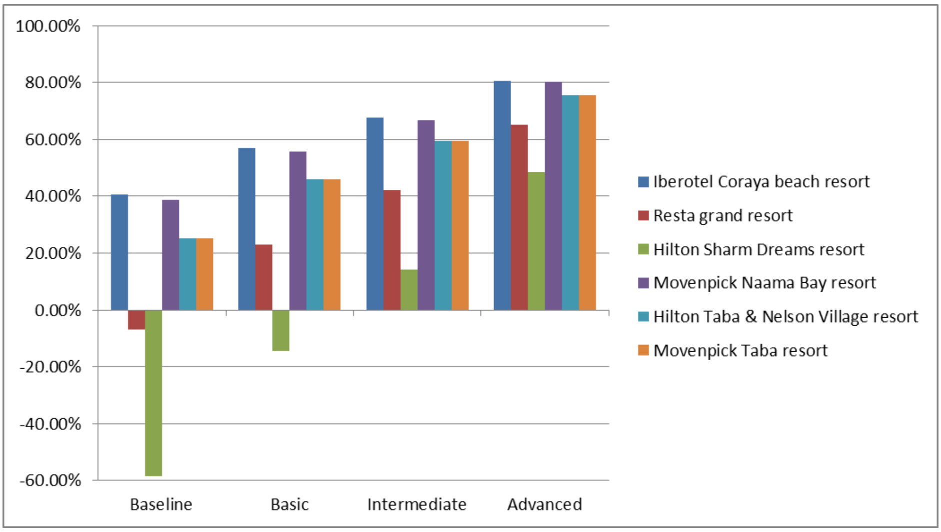


Figure 108 yearly water saving ratios of different scenarios for laundries in case studies **(Researcher)**

From Figure 108, the average water saving ratios can be concluded as followed:

By applying the baseline scenario to all case studies, low water saving ratios can be achieved. The average water saving ratio for baseline scenario in resorts can reach 10.73%.

By applying the basic scenario to all case studies, medium water saving ratios can be achieved. The average water saving ratio for basic scenario in resorts can reach 35.50%.

By applying the intermediate scenario to all case studies, high water saving ratios can be achieved. The average water saving ratio for intermediate scenario in resorts can reach 51.63%.

By applying the advanced scenario to all case studies, higher water saving ratios can be achieved. The average water saving ratio for advanced scenario in resorts can reach 70.98%.

5.2.5.5. Kitchen

The following figure presents the yearly water saving ratios of different scenarios for kitchens in case studies.

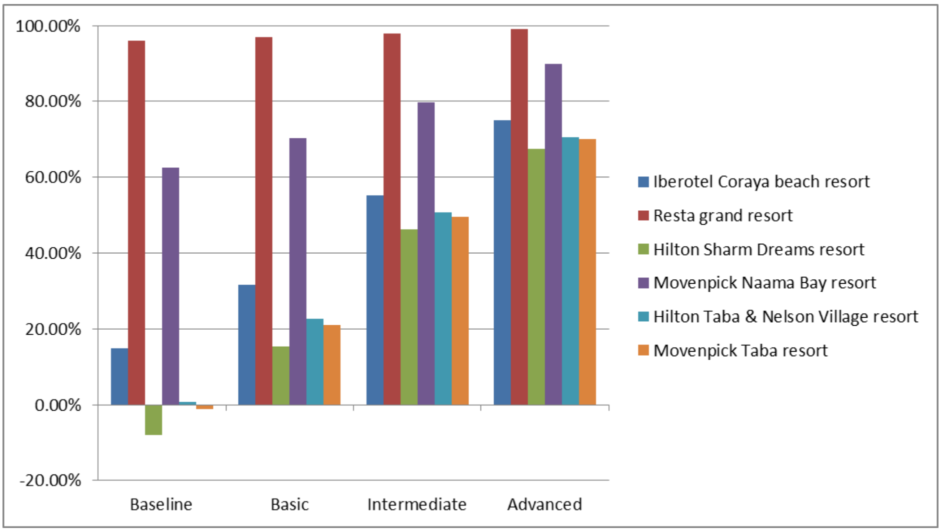


Figure 109 yearly water saving ratios of different scenarios for kitchens in case studies **(Researcher)**

From Figure 109, the average water saving ratios can be concluded as followed:

By applying the baseline scenario to all case studies, low water saving ratios can be achieved. The average water saving ratio for baseline scenario in resorts can reach 27.53%.

By applying the basic scenario to all case studies, medium water saving ratios can be achieved. The average water saving ratio for basic scenario in resorts can reach 42.97%.

By applying the intermediate scenario to all case studies, high water saving ratios can be achieved. The average water saving ratio for intermediate scenario in resorts can reach 63.26%.

By applying the advanced scenario to all case studies, higher water saving ratios can be achieved. The average water saving ratio for advanced scenario in resorts can reach 78.65%.

5.3. Architectural decision matrix for selecting water efficient techniques in eco-resorts

Although there are many opportunities for water conservation, the wide availability of mains water, sewage and storm water drainage connections means that water issues are rarely considered in resort projects. However, there are benefits to such considerations at the earliest stages of operation, and these are increasingly a requirement on the part of architects and planners.

The comparative analysis of case studies prove that water efficient techniques, either potable water efficient usage techniques or non-potable water applications, are rarely considered in resorts along the South Sinai and Red Sea coasts, the whole Egyptian Red Sea region.

The following tables define – based on previous data collected – the related guidelines for decisions made by architects to choose the suitable water-efficient techniques during design process or after the construction of a resort in the Red Sea region.

Water efficient techniques by resort functional sectors		Water usage	Water savings	Initial costs	Implementation during design	Implementation During operation	Spaces required Indoor	Spaces required Outdoor	Landscape arrangement
Bathroom	**Taps**	(L/min)						(Standard taps use 15 - 18 L/min)	
	Aerators / Flow restrictors	< 6	1	Low		Priority			
	Water-efficient taps	2	2	Midium		Priority			
	Sensor-operated taps		3	High		Priority			
	Showers	(L/min)						(Standard showers use 15 - 25 L/min)	
	Aerators / Flow restrictors		1	Low		Priority			
	Water-efficient heads	6 - 7	2	Midium		Priority			
	Sensor-operated heads		3	High		Priority			
	Toilets	(L/flush)						(Standard toilets use 6 L/flush)	
	Dual flush tank	3 - 6	1	Low		Priority			
	Dual flush valve	6 - 13.5	2	Low		Priority			
	Pressurized tanks	0 - 1.5	3	Midium		Priority			
	Compositing toilets	0 - 1.5	4	Midium	Priority	Alternative	Priority	Alternative	
	Vacuum toilets	0 - 1.5	4	High	Priority	Alternative	Priority	Alternative	
	Incinerating toilets	0 - 1.5	4	High	Priority	Alternative		Priority	Priority
	Urinals	(L/flush)						(Standard urinals use 6 L/flush)	
	Water-efficient urinals	2.8	1	Low		Priority			
	High-efficient urinals	1.5	2	Midium		Priority			
	Smart flush system	≤ 0.8	3	High		Priority			
	Waterless urinals	0	4	High		Priority			

Legend

Water savings	
(bar 1)	Low
(bar 2)	Midium
(bar 3)	High
(bar 4)	Highest

Initial costs	
(green)	(Savings)
(white)	Neutral
(light pink)	Low
(pink)	Midium
(red)	High

Design / Construction	
(dark grey)	Priority
(light grey)	Alternative

Indoor / Outdoor spaces	
(orange)	Priority
(light orange)	Alternative

Landscape arrangement	
(dark olive)	Priority
(light olive)	Alternative

Table 44 Decisions for architects concerning the selection of water-efficient techniques used in bathrooms

Water efficient techniques by resort functional sectors		Water usage	Water savings	Initial costs	Implementation		spaces required		Landscape arrange-ment
					during design	During operation	Indoor	Outdoor	
Kitchen	**Dishwashers** (Standard dishwashers use ≥ 75 L/rack)								
	Advanced rinse nozzles	High	1						
	Using door switches	Midium	2						
	Using steam doors	Midium	2						
	Sensor-operated system	Low	3						
	Graywater usage	Lowest	4						
	Taps (Standard taps use 9.5 - 15 L/min)	(L/min)							
	Aerators / Flow restrictors	≤ 9.5	1						
	Pedal-operated taps		3						
	Sensor-operated taps		3						
	Pre-rinse nozzles (Standard pre-rinse nozzles use 9.5 - 15 L/min)	(L/min)							
	High-efficient sprayers	6 - 10	1						
	Automatic shutoff valve		3						
	Ice machines (Water-cooled machines use X of water)								
	High-efficient (Air-cooled)	0.1*X	3						
	Garbage disposal								
	Using strainers / traps	Midium	2						

Legend

Water savings	
	Low
	Midium
	High
	Highest

Initial costs	
	(Savings)
	Neutral
	Low
	Midium
	High

Design / Construction	
	Priority
	Alternative

Indoor / Outdoor spaces	
	Priority
	Alternative

Landscape arrangement	
	Priority
	Alternative

Table 45 Decisions for architects concerning the selection of water-efficient techniques used in kitchen

	Water efficient techniques by resort functional sectors	Water usage	Water savings	Initial costs	Implementation during design	Implementation During operation	spaces required Indoor	spaces required Outdoor	Landscape arrange-ment
Laundry	**Washing machines**	(L/5kg fill)					(Standard machines use 180 L/5kg fill)		
	Computerized treatment	90	1	Midium	Priority	Alternative	Priority	Alternative	
	High-efficient machines	68	2	Midium		Priority			
	Cont. batch washer(tunnel)		2	Midium		Priority			
	Ozone laundry system	18	4	High	Priority	Alternative			
Recreation	**Swimming pools**								
	Efficient water cycle	High	1	Midium	Priority	Alternative	Priority	Alternative	
	Partial shading	Midium	2	Low	Priority	Alternative			
	Alternatives (Sea water)	Low	3	High	Priority			Priority	
	Landscape								
	Minimize paving	High	1	(Savings)	Priority	Alternative			Priority
	Trees for shad./wind breaks	High	1	Midium	Priority	Alternative		Priority	Priority
	Grouping similar plants	Midium	2	Neutral	Priority	Alternative			Priority
	Minimizing lawn areas	Midium	2	(Savings)	Priority	Alternative			Priority
	Using native plants	Midium	2	(Savings)	Priority	Alternative			Priority
	Using fine-coarse soils	Midium	2	Midium	Priority	Alternative			Alternative
	Mulching plants	High	1	Low		Priority			
	Sprinkler irrigation	Low	3	Midium	Priority	Alternative		Priority	Alternative
	Drip irrigation	Low	3	Midium	Priority	Alternative		Priority	Alternative
	Graywater usage	Lowest	4	High	Priority	Alternative		Priority	Alternative

Legend

Water savings	
(bar)	Low
(bar)	Midium
(bar)	High
(bar)	Highest

Initial costs	
(green)	(Savings)
(white)	Neutral
(light pink)	Low
(pink)	Midium
(red)	High

Design / Construction	
(dark grey)	Priority
(light grey)	Alternative

Indoor / Outdoor spaces	
(orange)	Priority
(light orange)	Alternative

Landscape arrangement	
(dark olive)	Priority
(light olive)	Alternative

Table 46 Decisions for architects concerning the selection of water-efficient techniques used in laundry and recreation

	Water efficient techniques by resort functional sectors	Water usage	Water savings	Initial costs	Implementation		spaces required		Landscape arrange-ment
					during design	During operation	Indoor	Outdoor	
Mechanical equipment	**Water / Steam boilers**								
	Manual blowdown control	Midium	2	Midium		Priority	Priority		
	Auto. blowdown control	Low	3	High		Priority	Priority		
	Maximizing condensate	Low	3	High		Priority	Priority		
	HVAC systems								
	Improving water-cooled	High (36%)	1	Low					
	Evaporative cooling		1	Low	Priority	Alternative	Priority		
	DMX system	Midium	2	Midium					
	Air-cooled systems	Lowest	4	Midium					
	Liquid coolers	Low	3	Midium					
	Water source geothermal	Midium	2	High					
	Sea / Lake water cooling	Low	3	High					
	Hybrid systems	Lowest	4	High					
	In-ground heat source pump	Lowest	4	High	Priority	Alternative	Priority	Alternative	
	Fire fighting								
	Graywater in hydrants	Low	3	Low	Priority	Alternative			
	Graywater in sprinklers	Low	3	Midium	Priority	Alternative			
	Graywater in regular flushes	Midium	2	Low	Priority	Alternative			

Legend

Water savings	
(bar)	Low
(bar)	Midium
(bar)	High
(bar)	Highest

Initial costs	
(colour)	(Savings)
(colour)	Neutral
(colour)	Low
(colour)	Midium
(colour)	High

Design / Construction	
(colour)	Priority
(colour)	Alternative

Indoor / Outdoor spaces	
(colour)	Priority
(colour)	Alternative

Landscape arrangement	
(colour)	Priority
(colour)	Alternative

Table 47 Decisions for architects concerning the selection of water-efficient mechanical equipment

	Water efficient techniques by resort functional sectors	Treated water quality	Initial costs	Implementation		spaces required		Landscape arrange-ment
				during design	During operation	Indoor	Outdoor	
Non-potable water sources	**Wastewater treatment**							
	Septic tanks	Low	Low	Priority			Priority	Priority
	Anaerobic treatment	High	Midium	Priority			Priority	Priority
	Aerobic treatment	High	Low	Priority			Priority	Priority
	Constructed wetlands	Midium	Midium	Priority			Priority	Priority
	Living machines	Highest	High	Priority			Priority	Priority
	Evapotranspiration	Highest	High	Priority			Priority	Priority
	MBR system	Highest	High	Priority			Priority	Priority
	Other sources							
	flushes from fire testing	High	Low		Priority			
	HVAC condensate	Highest	Low		Priority			

Legend

Treated water quality
Low
Midium
High
Highest

Initial costs
(Savings)
Neutral
Low
Midium
High

Design / Construction
Priority
Alternative

Indoor / Outdoor spaces
Priority
Alternative

Landscape arrangement
Priority
Alternative

Table 48 Decisions for architects concerning the selection of non-potable water sources

	Water efficient techniques by resort functional sectors	Water usage	Water savings	Initial costs	Implementation		spaces required		Landscape arrange-ment
					during design	During operation	Indoor	Outdoor	
Non-potable water applications	**Dual plumbing**								
	Toilets and urinals	Lowest	4						
	Laundry	Midium	2						
	HVAC	Low	3						
	Landscape								
	Shallow trenches	Midium	2						
	Evapotranspiration	Midium	2						
	Drip irrigation	Low	3						
	Outdoor usage								
	Public water features	High	1						
	Swimming pool back-wash	Midium	2						
	Road care / maintenance	Midium	2						
	Groundwater recharge								
	Surface spreading	Midium	2						
	Vadose zone injection	Midium	2						
	Direct injection	Low	3						

Legend

Water savings	
	Low
	Midium
	High
	Highest

Initial costs	
	(Savings)
	Neutral
	Low
	Midium
	High

Design / Construction	
	Priority
	Alternative

Indoor / Outdoor spaces	
	Priority
	Alternative

Landscape arrangement	
	Priority
	Alternative

Table 49 Decisions for architects concerning the selection of non-potable water applications

Chapter conclusions

From this chapter, some conclusions can be summarized as followed:

1. The Egyptian regulations, set by the Egyptian Tourism Development Authority (TDA) in 2003, concerning water efficiency in Red sea resorts are not equivalent to international green standards.

2. According to water consumption analysis of case studies, the main indoor water-consuming sectors in resorts can be orderly categorized from higher to lower as guestrooms, staff housing, public spaces, laundry and kitchens.

3. For bathroom taps and showers, the best water efficient technique is using sensor-operated units, which have high initial costs and can be implemented after resort construction.

4. For toilets, the best water efficient techniques are using pressurized tanks, compositing toilets, vacuum toilets or incinerating toilets. The vacuum and incinerating toilets have high initial costs while the pressurized tanks and compositing toilets have lower initial costs. The vacuum toilets, incinerating toilets and compositing toilets require indoor/outdoor spaces and can be implemented either before resort design or after resort construction, while the pressurized tanks can be implemented after resort construction without any spatial requirements.

5. For urinals, the best water efficient techniques are using waterless urinals or smart flush systems, which have high initial costs and can be implemented after resort construction.

6. For dishwashers, the best water efficient techniques are using graywater or sensor-operated systems, which have high initial costs and can be implemented after resort construction.

7. For kitchen taps and pre-rinse nozzles, the best water efficient techniques are using pedal-operated taps, sensor-operated taps or automatic shutoff valves, which can be implemented after resort construction. The sensor-operated taps and automatic shutoff valves have high initial costs while the pedal-operated taps have lower initial costs.

8. For ice machines, the best water efficient technique is using air-cooled systems, which have high initial costs and can be implemented either before resort design or after resort construction.

9. For water and steam boilers, the best water efficient techniques are using automatic blowdown control or maximizing condensate systems, which have high initial costs and can be implemented after resort construction with indoor space requirements.

10. For air conditioning systems, the best water efficient techniques are using air-cooled systems, sea/lake water cooling, liquid coolers, hybrid systems or in-ground heat source pump (IGHSP). The sea/lake water cooling, hybrid systems and in-ground heat source pump systems have high initial costs while the air-cooled systems and liquid coolers have lower initial costs. The in-ground heat source pump system can be implemented either before resort design or after resort construction with indoor/outdoor space requirements.

11. For firefighting systems, the best water efficient technique is using graywater for hydrants and sprinklers. Using graywater for hydrants has low initial costs while using graywater for sprinklers have higher initial costs. Using graywater for hydrants and sprinklers can be implemented either before resort design or after resort construction.

12. For laundry washing machines, the best water efficient technique is using Ozone laundry system, which has high initial costs and can be implemented either before resort design or after resort construction.

13. For swimming pools, the best water efficient technique is using non-potable water alternatives (seawater) which have high initial costs and can be implemented before resort design with outdoor space requirements.

14. For landscape, the best water efficient techniques are using sprinkler irrigation, drip irrigation or graywater. Graywater usage has high initial costs while the sprinkler irrigation and drip irrigation systems have lower initial costs. The sprinkler irrigation, drip irrigation and graywater usage can be implemented either before resort design or after resort construction with outdoor space requirements.

15. Concerning graywater sources, the best-treated water quality can be achieved using anaerobic treatment, aerobic treatment, living machines,

MBR system or evapotranspiration. The living machines, MBR and evapotranspiration systems have high initial costs while the anaerobic treatment and aerobic treatment have lower initial costs. All these techniques can be implemented before resort design with outdoor space requirements. Other sources include flushes from fire testing and HVAC condensate, which have low initial costs and can be implemented after resort construction.

16. Graywater can be used in dual-plumbing systems for toilets, urinals, laundries and HVAC systems with medium initial costs. Dual plumbing can be implemented before resort design with indoor space requirements.

17. Excess graywater can recharge groundwater aquifers for the possibility of reusing it during dry seasons. This process can be achieved using surface spreading, Vadose zone injection or direct injection which have respectively low, medium and high initial costs. All these techniques can be implemented either before resort design or after resort construction with outdoor space requirements.

Conclusion

From this thesis, main conclusions can be summarized as followed:

1. According to international Eco-tourism associations, some considerations for eco-resorts are conservation of nature, minimizing the use of energy and water, managing waste and supporting the local community.

2. Water conservation can be defined as any beneficial reduction in water loss, use or waste by implementation of water conservation or water efficiency measures.

3. Although there is a great demand for fresh water in the Red Sea area to cope with planned development, the Egyptian Red Sea region is considered one of the most regions in Egypt facing an extreme water shortage.

4. During operation phase, water-efficient techniques can reduce water use and pollution. Two main categories for these techniques are “Potable water applications” and “Non-potable water applications”.

5. In bathrooms, the best water efficient technique for taps and showers is using sensor-operated units. For toilets, techniques include pressurized tanks, compositing toilets, vacuum toilets or incinerating toilets. Concerning urinals, techniques include waterless urinals or smart flush systems.

6. In kitchens, the best water efficient techniques for dishwashers are using graywater or sensor-operated systems. For kitchen taps and pre-rinse nozzles, techniques include pedal-operated taps, sensor-operated taps or automatic shutoff valves. Concerning ice machines, techniques include air-cooled systems.

7. For boilers, the best water efficient techniques are using automatic blowdown control or maximizing condensate systems.

8. In mechanical zones, the best water efficient techniques for air conditioning systems are air-cooled systems, sea/lake water cooling, liquid coolers, hybrid systems or in-ground heat source pump (IGHSP). Concerning firefighting systems, techniques include using graywater for hydrants and sprinklers.

9. In laundries, the best water efficient technique for washing machines is using Ozone laundry system.

10. For swimming pools, the best water efficient technique is using non-potable water alternatives (sea water).

11. For landscape, the best water efficient techniques are using sprinkler irrigation, drip irrigation or graywater.

12. Concerning graywater sources, the best treated water quality can be achieved using anaerobic treatment, aerobic treatment, living machines, MBR system or evapotranspiration.

13. Graywater can be used in dual-plumbing systems for toilets, urinals, laundries and HVAC systems.

14. Excess graywater can recharge groundwater aquifers for the possibility of reusing it during dry seasons. This process can be achieved using surface spreading, Vadose zone injection or direct injection.

Recommendations

From this thesis, some recommendations might help to improve water efficiency in resorts along the Red Sea region in Egypt. These recommendations include:

1. Water should be conserved along the coasts of the Red Sea region, which is considered one of Egypt's priority zones for tourism development with high water demand expected in spite of facing a critical water shortage.

2. For resorts, water should be conserved during the whole project life cycle including design, construction and operation phases.

3. The Egyptian regulations, set by the Egyptian Tourism Development Authority (TDA) in 2003, concerning water efficiency in Red Sea resorts should be revised according to the latest international water efficient standards for eco-resorts.

4. Concerning non-potable water sources, priority should be placed for water treatment practices as they focus on reusing wastewater avoiding more exploitation of any potable water sources.

5. Natural water treatment systems are more preferable than conventional processes as they need less initial costs and energy.

6. Potable water should be efficiently used in all Red Sea resorts. This can be achieved by using water efficient fixtures and techniques in bathrooms, kitchens, laundries, mechanical systems, swimming pools and landscape.

7. Dual plumbing systems should be implemented in resorts to provide an applicable use of graywater for toilets and urinals flushing, some washing phases in laundries and internal cooling cycles in HVAC systems.

8. Landscape irrigation systems should make a full use of graywater instead of potable water sources using drip irrigation or shallow trench systems.

9. Concerning resort sectors, resorts should give priority to implement water efficient techniques in guestrooms, staff housing and landscape as they are the top consumers of water. After that come public spaces, laundries, kitchens, mechanical systems and swimming pools.

Appendix A: The design procedures for different water-efficient applications

A.1. Composting toilets

A.1.1. Design procedures

a. Estimate the daily composting toilet usage by establishing a building occupancy count and assuming 3 uses per person per 8-hour stay. [31]

b. Choose a self-contained or central system based on required capacity, design intent, and a sense of how the building will be operated and maintained. A central system will make more sense in most public, high-use facilities. [31]

c. Allocate space for a remote tank(s) as required by selected system type and required capacity from (Table 16 Typical composting toilet dimensions .

d. Allocate space for access and maintenance around the remote tank(s). Ensure that plan layout and building structure will permit connection of the water closet to the remote tank (if that option is selected). [31]

A.2. Graywater plumbing system

A.2.1. Design procedures

a. Conduct a water-use inventory for the proposed building. The inventory includes an estimate of the types of water usage and their respective amounts for a typical time frame. Table 50 can be used as a starting point for such an estimate for residential applications.

b. Establish appropriate applications for graywater usage and estimate the graywater quantity needed. Estimating techniques will vary depending upon the anticipated usage, an inquiry to a local agricultural extension agent or landscape professional is suggested for many potential graywater uses.

WATER USAGE	WATER OUTFLOW	OUTFLOW QUALITY
Clothes washing machine	Top loader: 30–50 gal [115–190 L]/load Front loader: 10 gal [38 L]/load @ 1.5 loads/week/adult @ 2.5 loads/week/child	Graywater
Dishwasher	5–10 gal [19–38 L]/load	Graywater
Shower	Low-flow: 20 gal [75 L]/day/person High-flow: 40 gal [150 L]/day/person	Graywater
Kitchen sink	5–15 gal [19–56 L]/day/person	Graywater

Table 50 Estimating graywater resources **(Kwok & Grondzik, 2007)**

c. Decide if graywater reuse is appropriate based upon the available graywater capacity, architectural and site considerations, and the quantity of water that could be utilized by potential graywater applications. [31]

d. Decide if treatment/storage or immediate reuse should be employed based upon design considerations and the relationship between graywater production and consumption over a representative period of time.

e. Determine whether filtration will be employed based upon the nature of the reuse application and storage needs.

f. Incorporate the graywater collection/storage elements into the project design.

A.3. Living machines

A.3.1. Design procedures

As a proprietary technology, there is no general guideline available for the sizing of a Living Machine (package treatment system). Living Machine design for a specific project will involve consulting with a system design specialist. For schematic design purposes, the following information should permit allocation of appropriate spaces. The values are based upon information from several existing Living Machine installations.

a. Determine the building wastewater load in gallons per day (gpd) [L/d]. Building design handbooks can provide values in support of this estimation. [31]

b. Estimate the approximate sizes of aerobic tank and clarifier using guiding tables in (Table 22 Approximate dimensions of Living Machine components for three system sizes (capacities)). If an on-site wetland will be used to facilitate the flow of processed water back into the ecosystem, estimate its size (also from the same tables).

c. Lay out a conditioned space for the aerobic digesters so that there is enough space for maintenance workers to walk around the tanks, prune plants, and conduct water quality tests. Allow space (10% more is suggested) for additional equipment including pumps, meters, piping, and a UV filter. If Living Machine tours are anticipated as part of the project design intent, provide for adequate circulation and "stop and look" spaces. [31]

d. Provide space nearby for a supplemental equipment room: 1.8 x 3m should suffice for a medium capacity system. [31]

e. The exterior space required for the anaerobic tanks is roughly equal to the space needed for the aerobic tanks. [31]

A.4. Rainwater harvesting

A.4.1. Design procedures

This procedure provides representative values for preliminary estimation purposes for domestic water use systems. Actual water quantities may vary widely from project to project and are highly climate dependent.

a. Plan for the use of low-flow plumbing devices. It makes no sense to embark on a water collection strategy without first reducing demand through appropriate selection of fixtures. Reduced flow fixtures can cut water demand by 25–50% (compared to conventional fixtures). [31]

b. Estimate the water needs of the building. Interior water needs typically include: water closets/urinals, showers, dishwashing, laundry and drinking/cooking water. Water consumption is expressed in gpd [L/d] (gallons [liters] per day); a per capita consumption would be multiplied by building occupancy. Annual water needs can be estimated by multiplying gpd [L/d] by 365 days. [31]

c. Determine available rainfall for the building site. Data are often available from government-source annual summaries.

d. Determine required catchment area to provide for the annual water needs of the project (considering design annual rainfall).The area of a roof used for catchment should be the projected horizontal area of the roof, not the actual surface area. In general, only 75% of average annual rainfall is actually going to be available for cistern storage (due to unavoidable losses such as evaporation and roof-washing cycles). [31]

e. Calculate cistern volume. The estimated capacity should be based upon the length of the most extensive rainless period obtained from local climatological data. Cistern capacity = (gpd [L/d] of usage) (days in rainless period). The volume can be calculated as $1m^3$ = 1000L. [31]

f. Establish cistern location. A cistern placed close to water usage locations is most logical and can reduce required pump capacity. An underground location can reduce visual impact and provide stability of water temperature. An above-ground location can provide an opportunity for visual impact.

g. Select or design cistern. This will be based upon the required volume, desired material, maintenance, and site considerations.

Appendix B: Calculation methodology for water consumption in resorts

B.1. Assuming water consumption scenarios

The Baseline scenario utilizes devices that comply with current building regulations. The Basic scenario utilizes basic water efficiency devices whilst the Intermediate scenario replaces some of these devices with more efficient devices. Finally, the advanced scenario utilized devices at the cutting edge of water conservation such as rainwater harvesting and waterless urinals.

In order to adequately account for the differences between hotel designs, such as whether or not they include restaurants, a modular approach has been used to model water consumption within hotels. This approach will enable more accurate and repeatable modeling of water consumption for proposed hotel developments.

The modules that have been used are: [38]

- Room water use (L/guest/day)
- Laundry water use (L/room/day)
- Employee water use (L/employee/day)
- Restaurant water use including restaurant employee water use (L/meal)

Due to the lack of robust data it has not, at this time, been possible to produce a module to model domestic-type water use in hotel gyms or swimming pools.

The modular approach is also necessary as some elements, such as showers in guest rooms, readily fit the proxy; whereas employee toilet use does not readily fit and must be apportioned evenly. Similarly, it is possible to model the water requirement for a meal in a restaurant but this must be adequately apportioned to the proxy figure. Apportioning factors are shown in Table 51.

Module	Factor
Hotel employees	0.5 (based on one employee per room)
Hotel restaurant	2 (based on two meals per hotel guest per day)

Table 51 Module apportioning factors **(Government, 2010)**

B.2. Water calculation inputs

B.2.1. Assumptions for water use factors of products

The calculation method requires the use of water use factors for products categorized in the following sectors shown in Table 52:

Hotel guests	**Total guest nights**		
	Males	50%	0
	Females	50%	0
	Toilet daily use	4	
	Full flush daily use	1.33	
	Half flush daily use	2.67	
	urinal daily use	H.flush daily use	
	Taps daily use (mins)	3	
	Shower daily use	0.9	guest nights
	Shower duration (mins)	8	
	Bath daily use	0.1	guest nights
Hotel restaurant	**Total food covers**		
	Water per meal (liters)	1.89	
	Ice per meal (kg)	0.33	
	Dishwasher rack per food cover	0.5	
	Each Pot & Pan sink filled twice per day (liters)	150	300
	Food preparation sink daily use (mins)	90	1.5 hours
	Pre-rinse nozzle daily use (mins)	61.20	1.02 to 4 hours
	Waste disposal daily use (mins)	180.00	for 1000000 food covers
Hotel laundry	**Total guestrooms**		
	Daily laundry (kg)	3.6	85% W.machines / total

Table 52 Assumptions for water use factors of products **(University, June 2009)**

Hotel staff	**Total employees**		
	Males	98%	0
	Females	2%	0
	Toilet daily use	3.85	
	Full flush daily use	1.28	
	Half flush daily use	2.57	
Hotel Public spaces	**Public toilet use (related to food covers)**	0.5	1.5
Miscellaneous	**Cleaning daily use (liters)**	298.4	
	Other daily uses (liters)	378	

Table 52 Assumptions for water use factors of products **(University, June 2009)** (continued)

B.2.2. Assumptions for water flow rates

The calculation method also requires the use of water flow rates for products categorized in four main scenarios as shown in Table 53:

Category	Details and units	Baseline	Basic	Intermediate	Advanced
Bathroom module					
Toilet (WC)	Full flush (liters/flush)	6	6	4.5	4.5
	Half flush (liters/flush)	0	4	3	3
	Rainwater & Graywater (%)				75%
Urinal	(liters/flush)	3.8	1.9	1.5	0
Hand basin	Tap flow rate (liters/min)	12	6	3	1.9
Bath	(liters/bath)	225	200	160	140
Shower	Shower flow rate (liters/min)	14	14	11	8
Non potable water use ratio	Rainwater & Graywater (%)				75%
Laundry module					
Washing machine	(liters/kg)	13.84	10	7.5	4.5
Main restaurant module					
Dishwasher	(liters/rack)	8	6.8	5	3
Ice maker	Water cooled device (liters/kg)	12.8	10	2	1.9
Pre-rinse nozzle	(liters/min)	10.3	10.3	6.2	4
Preparation taps	(liters/min)	12	8	5	3
Waste disposal	(liters/min)	17	17	17	0
Staff restaurant module					
Dishwasher	(liters/rack)	17	13	12	10
Preparation taps	(liters/min)	12	5	3	3

Table 53 Assumptions for water flow rates of products **(Government, 2010)**

Category	Details and units	Baseline	Basic	Intermediate	Advanced
Swimming pool module					
Non potable water use ratio	Rainwater & Graywater (%)		25%	50%	75%
Landscape module					
Non potable water use ratio	Rainwater & Graywater (%)			25%	50%

Table 53 Assumptions for water flow rates of products **(Government, 2010)** (continued)

B.2.3. Resort data survey

The calculation inputs should include the water readings (monthly) and other related data for a resort as shown in Tables 54 and 55:

Month		Total	Guest R.	Kitchen	Public	S. pools	Laundry	Staff H.	L.scape
Jan	31	36,428	15,538	728	7,255	2,376	1,416	7,507	1,608
Feb	28	34,832	12,980	690	6,929	2,107	1,295	7,831	3,000
Mar	31	33,734	13,345	1,369	6,786	2,459	1,837	7,932	6
Apr	30	46,029	18,755	1,907	8,415	2,503	2,234	9,970	2,245
May	31	49,092	20,351	2,101	7,090	3,889	2,383	10,020	3,258
Jun	30	42,786	15,536	1,622	5,125	3,257	2,077	10,150	5,019
Jul	31	42,412	15,078	1,524	5,359	2,977	2,059	10,290	5,125
Aug	31	24,950	2,556	424	1,211	1,722	1,211	9,500	8,326
Sep	30	32,259	10,341	930	3,684	1,310	1,501	9,473	5,019
Oct	31	32,722	11,184	1,000	5,400	1,843	1,609	6,561	5,125
Nov	30	25,492	8,309	1,411	4,956	1,931	1,775	4,518	2,592
Dec	31	31,158	13,049	1,032	6,343	2,321	1,591	5,359	1,464

Table 54 Example for monthly water readings in a resort **(Researcher)**

Month		Food C.	Guest N.	Staff	Laundry
Jan	31	27755	9287	300	47211
Feb	28	25965	8601	300	43183
Mar	31	42469	14804	300	61224
Apr	30	56585	18822	350	74478
May	31	61269	20423	350	79433
Jun	30	50268	16756	350	69230
Jul	31	48504	16168	350	68626
Aug	31	19447	6594	300	40371
Sep	30	32614	10701	300	50041
Oct	31	34038	11812	300	53624
Nov	30	43815	14289	300	59154
Dec	31	35441	11574	300	53020

Rooms no.	354

Table 55 Example for monthly water-calculation related data in a resort **(Researcher)**

B.3. Water calculation process

B.3.1. Monthly water consumption inputs

This calculation method requires water consumption inputs as shown in Table 56:

Month days	**31**
Total consumption	**36,428**
Guest R. consumption	**15,538**
Kitchen consumption	**728**
Public consumption	**7,255**
S. pools consumption	**2,376**
Laundry consumption	**1,416**
Staff H. consumption	**7,507**
L.scape consumption	**1,608**

Total employees	**300**	
Males	0.99	297
Females	0.01	3
Total guest nights	**9,287**	
Males	0.50	4,644
Females	0.50	4,644
Total guestrooms	**354**	
Total laundry weight	**47,211**	
Total food covers	**27,755**	

Dishwashers	2	
Pre-rinse nozzles	6	24
Preparation sinks	12	
Pot and pan sinks	6	

Table 56 Example for monthly water consumption inputs of a resort **(Researcher)**

B.3.2. Monthly water calculations for guestroom module

Monthly water calculations for guestrooms are processed as followed:

- **WC (full flush) =** Flow rate (full flush) x Daily use x Total guest nights
- **WC (half flush) =** Flow rate (half flush) x Daily use x Total guest nights
- **Wash hand basin =** Flow rate x Daily use x Total guest nights
- **Shower =** Flow rate x Daily use x Shower duration x Total guest nights
- **Bath =** Flow rate x Daily use x Total guest nights

Guestroom module	Baseline	Basic	Intermediate	Advanced	Existing Consumption
WC (full flush)	222,888.00	74,296.00	55,722.00	13,930.50	15,537,871.13
WC (half flush)	0.00	99,061.33	37,148.00	9,287.00	
Wash hand basin	334,332.00	167,166.00	83,583.00	52,935.90	
Shower	936,129.60	936,129.60	735,530.40	534,931.20	
Bath	208,957.50	185,740.00	148,592.00	130,018.00	
Room total (L)	1,702,307.10	1,462,392.93	1,060,575.40	741,102.60	15,537,871.13

Table 57 Example for monthly water calculations for guestroom module **(Researcher)**

B.3.3. Monthly water calculations for staff module

Monthly water calculations for staff are processed as followed:

Female employees

- **WC (full flush) =** Flow rate (full flush) x Daily use x No. of female employees x Month days
- **WC (half flush) =** Flow rate (half flush) x Daily use x No. of female employees x Month days
- **Wash hand basin =** Flow rate x Daily use x No. of female employees x Month days
- **Shower =** Flow rate x Shower duration x No. of female employees

Male employees

- **Urinal =** Flow rate x Daily use x No. of male employees x Month days
- **WC (full flush) =** Flow rate (full flush) x Daily use x No. of male employees x Month days
- **Wash hand basin =** Flow rate x Daily use x No. of male employees x Month days
- **Shower =** Flow rate x Shower duration x No. of male employees

Staff kitchen

- **Pre-rinse nozzle =** Flow rate x Daily use x No. of staff kitchen pre-rinse nozzles x Month days
- **Preparation sink =** Flow rate x Daily use x No. of staff kitchen preparation sinks x Month days
- **Pot-and-pan sink =** Daily use x No. of staff kitchen pot-and-pan sinks x Month days
- **Dishwasher =** Flow rate x Rack per food cover x Total staff food cover

- **Water used in food =** Water per meal x Total staff food cover
- **Ice making =** Flow rate x Ice per meal x Total staff food cover
- **Cleaning =** Daily use x Month days
- **Waste disposal =** Flow rate x Daily use x Month days

Staff module

	Baseline	Basic	Intermediate	Advanced	Existing Consumption
Female employees					
WC (full flush)	2,148.30	716.10	537.08	134.27	
WC (half flush)	0.00	954.80	716.10	179.03	
Wash hand basin	3,348.00	1,674.00	837.00	530.10	
Shower	336.00	336.00	264.00	192.00	
Male employees					
Urinal	89,798.94	44,899.47	35,446.95	0.00	
WC (full flush)	70,893.90	70,893.90	53,170.43	13,292.61	
Wash hand basin	331,452.00	165,726.00	82,863.00	52,479.90	
Shower	33,264.00	33,264.00	26,136.00	19,008.00	7,507,000.00
Staff kitchen use					
Pre-rinse nozzle	58,664.48	58,664.48	35,312.60	22,782.32	
Preparation sink	201,020.50	83,758.54	50,255.12	50,255.12	
Pot and pan sink	27,919.51	20,939.64	13,959.76	6,979.88	
Dishwasher	118,041.25	90,266.84	83,323.24	69,436.03	
Water used in food	26,246.82	26,246.82	26,246.82	26,246.82	
Ice making	58,659.56	45,827.78	9,165.56	8,707.28	
Cleaning	2,314.22	2,314.22	1,735.66	1,735.66	
Waste disposal	47,463.17	47,463.17	47,463.17	0.00	
Staff total (L)	**1,071,570.65**	**693,945.76**	**467,432.48**	**271,959.02**	**7,507,000.00**

Table 58 Example for monthly water calculations for staff module **(Researcher)**

B.3.4. Monthly water calculations for kitchen module

Monthly water calculations for kitchen are processe as followed:

- **Pre-rinse nozzle =** Flow rate x Daily use x No. of main kitchen pre-rinse nozzles x Month days
- **Preparation sink =** Flow rate x Daily use x No. of main kitchen preparation sinks x Month days
- **Pot-and-pan sink =** Daily use x No. of main kitchen pot-and-pan sinks x Month days
- **Dishwasher =** Flow rate x Rack per food cover x Total guest food cover
- **Water used in food =** Water per meal x Total guest food cover
- **Ice making =** Flow rate x Ice per meal x Total guest food cover

- **Cleaning =** Daily use x Month days
- **Waste disposal =** Flow rate x Daily use x Month days

Kitchen module	Baseline	Basic	Intermediate	Advanced	Existing Consumption
Pre-rinse nozzle	58,582.48	58,582.48	35,263.24	22,750.48	728,059.18
Preparation sink	200,739.50	133,826.33	83,641.46	50,184.88	
Pot and pan sink	27,880.49	20,910.36	13,940.24	6,970.12	
Dishwasher	55,471.18	47,150.50	34,669.48	20,801.69	
Water used in food	26,210.13	26,210.13	26,210.13	26,210.13	
Ice making	58,577.56	45,763.72	9,152.74	8,695.11	
Cleaning	2,310.98	2,310.98	1,733.24	1,733.24	
Waste disposal	47,396.83	47,396.83	47,396.83	0.00	
Restaurant total (L)	**477,169.14**	**382,151.34**	**252,007.36**	**137,345.64**	**728,059.18**

Table 59 Example for monthly water calculations for kitchen module **(Researcher)**

B.3.5. Monthly water calculations for laundry module

Monthly water calculations for laundry are processed as followed:

- **Washing machine =** Flow rate x Daily use x Total laundry weight
- **Steam units =** Flow rate x Daily use x Total laundry weight

Laundry module	Baseline	Basic	Intermediate	Advanced	Existing Consumption
Washing machine	555,389.97	401,293.33	300,970.00	180,582.00	1,416,329.40
Steam units	98,009.99	70,816.47	53,112.35	31,867.41	
Laundry total (L)	**653,399.96**	**472,109.80**	**354,082.35**	**212,449.41**	**1,416,329.40**

Table 60 Example for monthly water calculations for laundry module **(Researcher)**

B.3.6. Monthly water calculations for public module

Monthly water calculations for public spaces are processed as followed:

Visitors WCs

- **Urinal =** Flow rate x Use per food covers x Total male guest food covers
- **WC (full flush) =** Flow rate (full flush) x Use per food covers x Total guest food covers

- **WC (half flush) =** Flow rate (half flush) x Use per food covers x Total female guest food covers
- **Wash hand basin =** Flow rate x Use per food covers x Total guest food covers

Miscellaneous

- **Cleaning =** Daily use x Month days
- **HVAC and firefighting =** Total water used x (1 – Non-potable water use ratio)
- **Outdoor showers =** Flow rate x Duration (2 mins) x Total users
- **Other uses =** Other daily uses x Month days

Public module	Baseline	Basic	Intermediate	Advanced	Existing Consumption
Visitors WC					
Urinal	19,761.61	9,880.80	7,800.63	0.00	7,254,740.29
WC (full flush)	93,607.61	62,405.07	46,803.80	11,700.95	
WC (half flush)	0.00	20,801.69	15,601.27	3,900.32	
Wash hand basin	124,810.14	62,405.07	31,202.54	19,761.61	
Miscellaneous					
Cleaning	9,250.40	9,250.40	6,937.80	6,937.80	
HVAC and fire fighting	6,003,573.62	6,003,573.62	4,502,680.22	3,001,786.81	
Outdoor showers	130,018.00	130,018.00	102,157.00	74,296.00	
Other uses	11,718.00	11,718.00	8,788.50	8,788.50	
Public total (L)	**6,392,739.38**	**6,310,052.66**	**4,721,971.76**	**3,127,171.99**	**7,254,740.29**

Table 61 Example for monthly water calculations for public module **(Researcher)**

B.3.7. Monthly water calculations for swimming pool module

Monthly water calculations for swimming pools are processed as followed:

- **Swimming pools =** Swimming pools consumption x (1 – Non-potable water use ratio)

Swimming pool module	Baseline	Basic	Intermediate	Advanced	Existing Consumption
Swimming pools	2,376,000.00	1,782,000.00	1,188,000.00	594,000.00	2,376,000.00
Laundry total (L)	**2,376,000.00**	**1,782,000.00**	**1,188,000.00**	**594,000.00**	**2,376,000.00**

Table 62 Example for monthly water calculations for swimming pool module **(Researcher)**

B.3.8. Monthly water calculations for landscape module

Monthly water calculations for landscape are processed as followed:

- **Irrigation =** Landscape consumption x (1 – Non-potable water use ratio)

Landscape module

	Baseline	Basic	Intermediate	Advanced	Existing Consumption
Irrigation	1,608,000.00	1,608,000.00	1,206,000.00	804,000.00	1,608,000.00
Laundry total (L)	**1,608,000.00**	**1,608,000.00**	**1,206,000.00**	**804,000.00**	**1,608,000.00**

Table 63 Example for monthly water calculations for landscape module **(Researcher)**

B.3.9. Monthly total water consumption for a resort

Monthly water consumption can be calculated in different scenarios as shown:

	Baseline	Basic	Intermediate	Advanced	Existing
Guestrooms	1,702.31	1,462.39	1,060.58	741.10	15,537.87
Staff	1,071.57	693.95	467.43	271.96	7,507.00
Kitchen	477.17	382.15	252.01	137.35	728.06
Laundry	653.40	472.11	354.08	212.45	1,416.33
Public	6,392.74	6,310.05	4,721.97	3,127.17	7,254.74
S. pools	2,376.00	1,782.00	1,188.00	594.00	2,376.00
Landscape	1,608.00	1,608.00	1,206.00	804.00	1,608.00
Total fresh water (m3)	**14,281.19**	**12,710.65**	**9,250.07**	**5,888.03**	**36,428.00**

Table 64 Example for monthly total water consumption for a resort **(Researcher)**

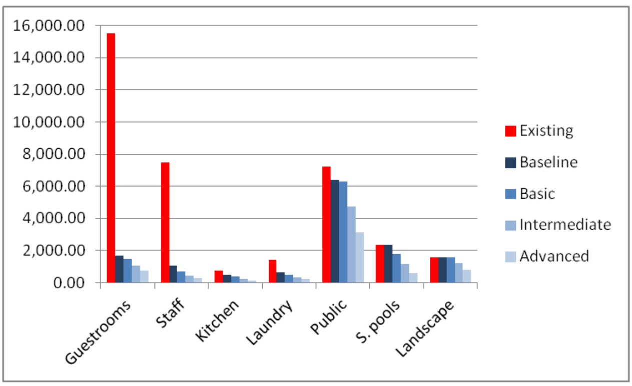


Figure 110 Chart for monthly water consumption (m^3) of the different sectors in a resort **(Researcher)**

B.4. Water calculation outputs

B.4.1. Monthly water consumption charts

Monthly water consumption can be presented in charts for different scenarios as shown in Figures 111 and 112:

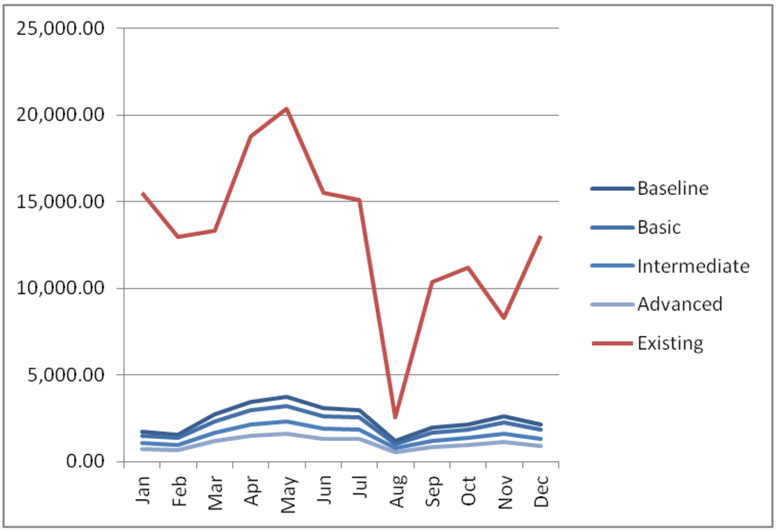


Figure 111 Chart for monthly water consumption (m^3) of guestrooms in a resort **(Researcher)**

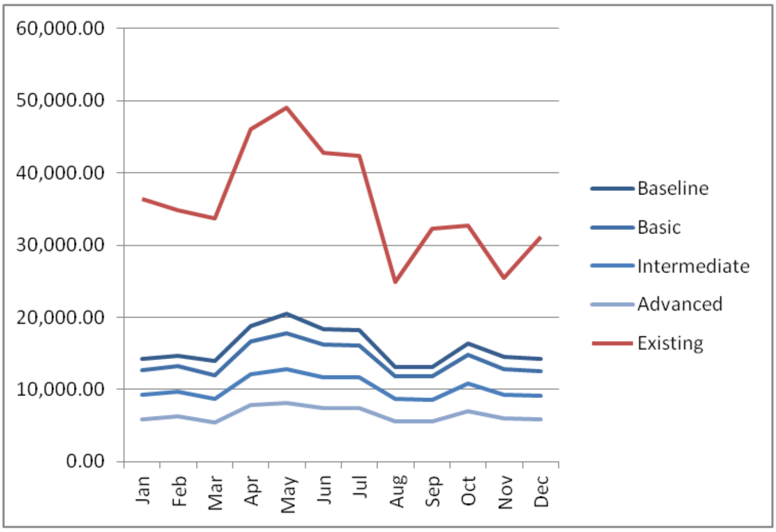


Figure 112 Chart for monthly total water consumption (m^3) in a resort **(Researcher)**

B.4.2. Yearly charts for water consumption ratios by sectors

Yearly water consumption ratios of different sectors can be presented in charts as shown in Figure 113:

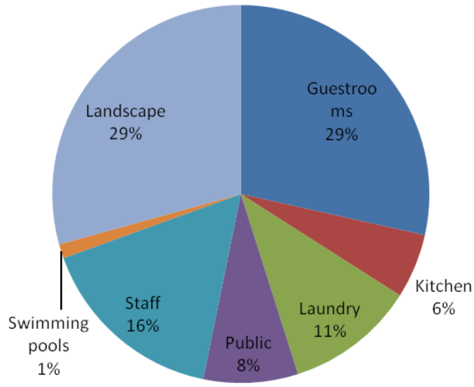


Figure 113 Chart for yearly water consumption ratios of different sectors in a resort **(Researcher)**

B.4.3. Yearly water consumption charts

Yearly water consumption can be presented in charts for different scenarios as shown in Figure 114:

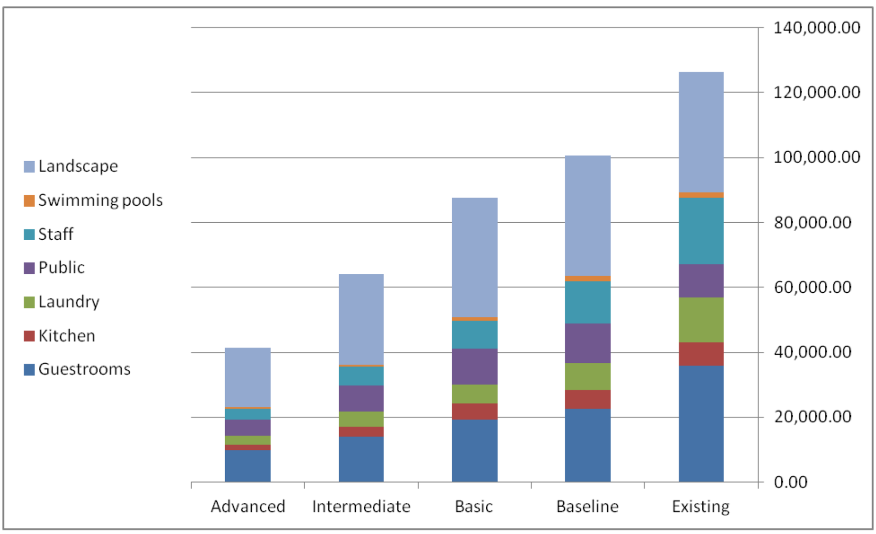


Figure 114 Chart for yearly water consumption (m^3) by sectors in different scenarios **(Researcher)**

Appendix C: Data survey for case studies

C.1. Operation data and water readings

C.1.1. General data

General data for case studies include:

- Room capacity

C.1.2. Monthly operation data

Monthly operation data for case studies include:

- No. of guest nights
- No. of Staff members
- Total food cover
- Total laundry loads

C.1.3. Monthly water readings

Monthly water readings for case studies are recorded for main sectors including:

- Guestrooms
- Staff housing
- Main kitchen
- Laundry
- Public spaces
- Swimming pools
- Landscape

C.1.4. Templates for case studies

Data survey templates for selected case studies are shown in Table 65:

Iberotel Coraya beach resort, Marsa Alam

Month		Total	Guest R.	Kitchen	Public	S. pools	Laundry	Staff H.	L.scape	Food C.	Guest N.	Staff	Laundry
Jan	31	**10,658**	4,254	939	1,028	91	1,030	1,870	1,446	44301	14767	310	61918
Feb	28	**9,881**	662	48	485	92	608	1,302	6,683	6231	2077	260	23767
Mar	31	**9,059**	1,444	202	517	96	952	1,214	4,634	15039	5013	260	33205
Apr	30	**11,011**	2,528	426	833	99	1,210	1,767	4,149	25476	8492	310	45192
May	31	**10,852**	2,784	509	875	150	1,260	1,829	3,445	28998	9666	310	48961
Jun	30	**10,951**	2,231	351	829	156	1,120	1,852	4,411	22485	7495	310	42659
Jul	31	**11,015**	2,057	320	795	170	1,054	1,799	4,820	21423	7141	310	42548
Aug	31	**11,090**	2,455	420	844	177	1,250	1,819	4,125	25563	8521	310	46053
Sep	30	**11,106**	3,478	683	959	132	1,100	1,848	2,906	35052	11684	310	53299
Oct	31	**10,107**	4,605	988	1,033	126	1,350	1,850	155	47958	15986	360	68951
Nov	30	**11,569**	5,823	1,323	1,176	120	1,365	1,699	63	58686	19562	360	77119
Dec	31	**8,963**	3,661	760	863	119	1,685	1,717	158	38130	12710	310	56693

Rooms no.	364

Resta grand resort, Marsa Alam

Month		Total	Guest R.	Kitchen	Public	S. pools	Laundry	Staff H.	L.scape	Food C.	Guest N.	Staff	Laundry
Jan	31	**8,425**	2,154	762	542	69	321	1,952	2,625	667	748	427	20532
Feb	28	**8,442**	2,654	815	448	86	425	1,634	2,380	645	211	362	19624
Mar	31	**10,394**	3,144	1,231	500	52	618	1,824	3,025	790	241	316	36073
Apr	30	**12,196**	4,254	1,452	349	42	714	1,248	4,137	962	409	302	57119
May	31	**15,042**	4,852	1,325	731	66	793	2,654	4,621	1006	359	288	56138
Jun	30	**14,228**	4,632	1,732	613	74	724	2,218	4,235	1115	356	275	55475
Jul	31	**14,327**	4,126	1,364	734	81	713	2,657	4,652	936	455	302	56103
Aug	31	**14,478**	4,852	1,842	601	84	698	2,170	4,231	1027	424	305	58127
Sep	30	**15,044**	5,321	997	562	90	834	2,009	5,231	1173	525	315	57395
Oct	31	**14,267**	4,952	957	565	98	821	2,023	4,851	1091	557	342	56365
Nov	30	**8,329**	2,314	844	541	91	436	1,955	2,148	640	595	340	54361
Dec	31	**7,962**	2,314	754	512	86	451	1,862	1,983	625	423	369	54924

Rooms no.	400

Table 65 Data survey templates for case studies **(Researcher)**

Hilton Sharm Dreams resort, Sharm El-Sheikh

Month		Total	Guest R.	Kitchen	Public	S. pools	Laundry	Staff H.	L.scape	Food C.	Guest N.	Staff	Laundry
Jan	31	22,084	13,217	1,012	1,969	1,909	1,781	2,196	0	56838	5981	521	142407
Feb	28	9,745	5,657	194	700	996	698	1,500	0	11774	1597	519	112265
Mar	31	12,679	7,057	260	1,903	762	901	1,796	0	22068	2897	513	208324
Apr	30	21,038	11,977	368	4,131	1,133	1,489	1,940	0	54342	6270	482	162590
May	31	20,289	11,318	443	3,886	1,218	1,752	1,672	0	57424	6470	459	149705
Jun	30	23,119	12,662	493	4,963	1,595	1,594	1,812	0	55040	5923	457	216618
Jul	31	27,423	16,333	513	5,278	1,601	1,842	1,856	0	78995	7699	440	213954
Aug	31	25,037	14,790	541	4,613	1,339	1,678	2,076	0	84075	7675	459	181472
Sep	30	23,689	14,145	487	4,165	1,369	1,547	1,976	0	69576	6954	479	169420
Oct	31	25,091	14,065	519	4,073	2,563	1,607	2,264	0	71838	7197	484	171917
Nov	30	22,929	13,315	461	2,937	2,506	1,590	2,120	0	65995	6791	484	165694
Dec	31	19,724	11,400	520	1,723	2,849	1,240	1,992	0	47772	4899	484	133140

Rooms no.	394

Movenpick Naama Bay resort, Sharm El-Sheikh

Month		Total	Guest R.	Kitchen	Public	S. pools	Laundry	Staff H.	L.scape	Food C.	Guest N.	Staff	Laundry
Jan	31	22,258	4,650	558	1,550	930	930	4,340	9,300	19184	8859	335	62590
Feb	28	20,300	4,060	532	1,400	840	868	4,200	8,400	3942	2028	325	15255
Mar	31	23,777	4,960	651	1,705	1,085	961	4,805	9,610	4373	2137	300	18280
Apr	30	24,142	5,400	682	1,800	1,200	960	4,800	9,300	11482	5320	295	34855
May	31	25,606	5,890	589	1,860	1,395	992	4,960	9,920	10356	4665	293	48010
Jun	30	26,160	5,400	960	1,950	1,200	1,050	4,800	10,800	6696	3291	290	32830
Jul	31	28,179	5,580	744	2,170	1,550	1,085	5,580	11,470	12738	6918	294	44030
Aug	31	30,154	5,425	558	2,325	1,395	1,116	5,735	13,600	9602	4427	289	37140
Sep	30	28,380	5,310	870	2,400	1,470	990	5,250	12,090	12119	6450	288	48970
Oct	31	24,087	4,960	837	1,860	1,240	930	4,340	9,920	19116	8859	289	58030
Nov	30	22,500	4,650	900	1,800	1,200	900	4,050	9,000	23009	10777	292	64910
Dec	31	23,005	4,650	840	1,860	1,178	930	4,247	9,300	10982	5082	283	52820

Rooms no.	302

Table 65 Data survey templates for case studies **(Researcher)** (continued)

Hilton Taba & Nelson Village resort, Taba

Month		Total	Guest R.	Kitchen	Public	S. pools	Laundry	Staff H.	L.scape	Food C.	Guest N.	Staff	Laundry
Jan	31	**11,474**	4,766	1,529	954	175	1,463	2,587	0	82082	20466	580	94344
Feb	28	**4,534**	1,654	281	628	150	718	1,103	0	20634	5430	304	30661
Mar	31	**5,297**	509	344	1,069	75	773	2,528	0	23402	6809	304	38995
Apr	30	**8,466**	2,619	837	1,039	73	1,308	2,590	0	47913	14125	472	74274
May	31	**8,108**	1,843	562	1,347	99	1,115	3,142	0	38481	10477	472	62941
Jun	30	**11,085**	3,451	743	1,333	207	1,281	2,962	1,109	44933	12690	472	77074
Jul	31	**13,146**	4,607	1,395	1,327	150	1,428	2,925	1,315	74855	20462	580	100684
Aug	31	**12,767**	4,691	1,237	1,374	213	1,519	3,095	638	68084	19414	580	98800
Sep	30	**11,004**	3,676	749	1,295	128	1,510	2,546	1,100	42420	14435	472	78740
Oct	31	**12,084**	4,490	1,164	1,183	132	1,705	2,807	604	61943	20833	580	90186
Nov	30	**8,937**	2,550	892	1,082	148	2,040	2,225	0	47415	16472	472	66588
Dec	31	**6,129**	1,073	386	697	156	1,459	2,358	0	27860	9578	472	70220

Rooms no.	400

Movenpick Taba resort, Taba

Month		Total	Guest R.	Kitchen	Public	S. pools	Laundry	Staff H.	L.scape	Food C.	Guest N.	Staff	Laundry
Jan	31	**11,450**	3,767	1,114	1,280	38	1,551	3,201	500	56499	18833	471	100005
Feb	28	**10,630**	388	33	414	537	761	1,365	7,132	5814	1938	356	32500
Mar	31	**18,210**	1,486	301	1,107	796	819	3,128	10,573	22284	7428	381	41335
Apr	30	**21,550**	3,399	1,049	1,591	764	1,386	3,205	10,156	50982	16994	397	78730
May	31	**20,810**	1,805	413	1,413	848	1,182	3,888	11,261	27072	9024	376	66717
Jun	30	**21,460**	3,607	1,134	1,756	696	1,358	3,665	9,244	54102	18034	403	81698
Jul	31	**27,420**	4,533	1,564	2,165	982	1,514	3,619	13,043	67989	22663	381	106725
Aug	31	**27,240**	4,377	1,473	2,174	964	1,610	3,830	12,811	65655	21885	395	104728
Sep	30	**25,060**	3,081	919	1,614	1,029	1,600	3,150	13,667	46212	15404	390	83464
Oct	31	**22,210**	3,706	1,248	1,726	717	1,807	3,473	9,532	55590	18530	334	95597
Nov	30	**22,840**	3,413	1,141	1,514	830	2,162	2,753	11,026	51192	17064	324	70584
Dec	31	**21,360**	3,139	931	1,431	798	1,546	2,919	10,597	47088	15696	390	74434

Rooms no.	424

Table 65 Data survey templates for case studies **(Researcher)** (continued)

C.2. Photography of used water techniques

Pictures are categorized according to main water sectors including:

C.2.1. Water desalination

Pictures taken in case studies for Reverse Osmosis filtration tubes and Sand filters are shown below:

Figure 115 Left: Reverse Osmosis filtration tubes, Right: Sand filters **(Photographed in Hilton Sharm Dreams resort by the researcher)**

Figure 116 Left: Reverse Osmosis filtration tubes, Right: Sand filters **(Photographed in Movenpick Naama Bay resort by the researcher)**

Figure 117 Sand filters **(Photographed in Resta grand resort by the researcher)**

C.2.2. Water storage

Pictures taken in case studies for main water tanks are shown below:

Figure 118 Left: Water tanks **(Photographed in Hilton Sharm Dreams resort by the researcher)**, Right: Domestic water tanks **(Photographed in Movenpick Taba resort by the researcher)**

C.2.3. Boilers

Pictures taken in case studies for boilers are shown below:

Figure 119 Left: Main boilers **(Photographed in Hilton Sharm Dreams resort by the researcher)**, Right: Main boilers **(Photographed in Movenpick Taba resort by the researcher)**

Figure 120 Left: Main boilers, Right: Steam boilers **(Photographed in Movenpick Naama Bay resort by the researcher)**

Figure 121 Left: Main boilers, Right: Internal water boilers **(Photographed in Hilton Taba & Nelson Village resort by the researcher)**

Figure 122 Left: Main boilers, Right: Steam boilers **(Photographed in Resta grand resort by the researcher)**

C.2.4. Guestrooms

Pictures taken in case studies for fixtures of guestroom bathrooms are shown below:

Figure 123 Left: Taps (aerators used), Right: toillets (single flush) **(Photographed in Hilton Taba & Nelson Village resort by the researcher)**

Figure 124 Showerheads (water-rated) **(Photographed in Hilton Taba & Nelson Village resort by the researcher)**

Figure 125 Left: Showerheads (water-rated), Right: Infra-red urinals (public bathrooms) **(Photographed in Movenpick Taba resort by the researcher)**

Figure 126 Left: Taps (aerators used), Right: Bidets and toillets (dual-flush) **(Photographed in Resta grand resort by the researcher)**

C.2.5. Kitchens

Pictures taken in case studies for dishwashers and taps are shown below:

Figure 127 Left: Main dishwasher, Right: Secondary dishwasher **(Photographed in Hilton Sharm Dreams resort by the researcher)**

Figure 128 Left: Main dishwasher **(Photographed in Movenpick Naama Bay resort by the researcher)**, Right: Main dishwasher **(Photographed in Hilton Taba & Nelson Village resort by the researcher)**

Figure 129 Left: Main dishwasher, Right: Secondary dishwasher **(Photographed in Resta grand resort by the researcher)**

Figure 130 Left: Taps (flow restrictors used), Right: Pedal-operated taps **(Photographed in Movenpick Taba resort by the researcher)**

C.2.6. Laundry

Pictures taken in case studies for clothes washing machines are shown below:

Figure 131 Left: Clothes washing machines **(Photographed in Hilton Sharm Dreams resort by the researcher)**, Right: Clothes washing machines **(Photographed in Movenpick Naama Bay resort by the researcher)**

Figure 132 Left: Clothes washing machines, Right: Steam boiler for dryers (steam trap) **(Photographed in central laundry service shared between Hilton Taba & Nelson Village resort and Movenpick Taba resort by the researcher)**

Figure 133 Left: Clothes washing machines, Right: Clothes washing machines **(Photographed in Resta grand resort by the researcher)**

Figure 134 Clothes washing machines **(Photographed in Iberotel Coraya beach resort by the researcher)**

C.2.7. HVAC

Pictures taken in case studies for chillers are shown below:

Figure 135 Left: Chiller (Water-cooled system) **(Photographed in Hilton Taba & Nelson Village resort by the researcher)**, Right: Chiller (Water-cooled system) **(Photographed in Movenpick Taba resort by the researcher)**

Figure 136 Chiller (Water-cooled system) **(Photographed in Hilton Sharm Dreams resort by the researcher)**

C.2.8. Swimming pools

Pictures taken in case studies for pumps and sand filters are shown below:

Figure 137 Left: Pumps, Right: Sand filters **(Photographed in Hilton Taba & Nelson Village resort by the researcher)**

Figure 138 Left: Pumps, Right: Sand filters **(Photographed in Hilton Sharm Dreams resort by the researcher)**

C.2.9. Water treatment

Pictures taken in case studies for water treatment phases are shown below:

Figure 139 Left: Aeration, Right: Water tanks **(Photographed in central water treatment plant shared between Hilton Taba & Nelson Village resort and Movenpick Taba resort by the researcher)**

Figure 140 Left: Sludge dewatering system, Right: Final filteration **(Photographed in central water treatment plant shared between Hilton Taba & Nelson Village resort and Movenpick Taba resort by the researcher)**

Figure 141 Left: Aeration, Right: Final filtration **(Photographed in Hilton Sharm Dreams resort by the researcher)**

Figure 142 Left: Sand filters, Right: Irrigation pumps **(Photographed in Movenpick Naama Bay resort by the researcher)**

C.3. Proposed yearly water-efficient scenarios

Tables from 66 to 71 present all proposed reductions in water consumption according to different water-efficient scenarios (calculated based on methodology shown in Appendix C). Tables are categorized according to main sectors for all case studies as shown:

Resort sectors	Existing	Baseline	Basic	Intermediate	Advanced
Guestrooms	35,982.69	22,566.80	19,386.35	14,059.62	9,824.50
Share ratio	41.01%	25.72%	22.10%	16.02%	11.20%
Consumption ratio	100.00%	62.72%	53.88%	39.07%	27.30%
Kitchen	6,970.28	5,926.39	4,764.96	3,118.79	1,747.97
Share ratio	7.94%	6.75%	5.43%	3.55%	1.99%
Consumption ratio	100.00%	85.02%	68.36%	44.74%	25.08%
Laundry	13,984.00	8,309.05	6,003.65	4,502.73	2,701.64
Share ratio	15.94%	9.47%	6.84%	5.13%	3.08%
Consumption ratio	100.00%	59.42%	42.93%	32.20%	19.32%
Public	10,235.98	12,199.40	11,011.96	8,102.09	5,082.16
Share ratio	11.67%	13.90%	12.55%	9.23%	5.79%
Consumption ratio	100.00%	119.18%	107.58%	79.15%	49.65%
Staff	20,564.83	12,990.87	8,419.18	5,671.37	3,304.44
Share ratio	23.44%	14.81%	9.60%	6.46%	3.77%
Consumption ratio	100.00%	63.17%	40.94%	27.58%	16.07%
Total consumption (m^3)	**87,737.78**	**61,992.50**	**49,586.09**	**35,454.60**	**22,660.71**
Consumption ratio	100.00%	70.66%	56.52%	40.41%	25.83%
Total water cost (EGP)	579,069.33	409,150.50	327,268.22	234,000.36	149,560.70

(6.60 EGP per 1 m^3 of desalinated water)

Table 66 Proposed yearly water-efficient scenarios by indoor sectors in Iberotel Coraya beach resort, Marsa Alam **(Researcher)**

Resort sectors	Existing	Baseline	Basic	Intermediate	Advanced
Guestrooms	45,569.00	972.04	835.05	605.60	423.18
Share ratio	46.45%	0.99%	0.85%	0.62%	0.43%
Consumption ratio	100.00%	2.13%	1.83%	1.33%	0.93%
Kitchen	14,075.00	561.80	427.92	284.43	143.92
Share ratio	14.35%	0.57%	0.44%	0.29%	0.15%
Consumption ratio	100.00%	3.99%	3.04%	2.02%	1.02%
Laundry	7,548.00	8,058.15	5,822.36	4,366.77	2,620.06
Share ratio	7.69%	8.21%	5.94%	4.45%	2.67%
Consumption ratio	100.00%	106.76%	77.14%	57.85%	34.71%
Public	6,698.54	2,993.16	2,990.44	2,244.98	1,560.85
Share ratio	6.83%	3.05%	3.05%	2.29%	1.59%
Consumption ratio	100.00%	44.68%	44.64%	33.51%	23.30%
Staff	24,206.00	19,690.00	11,808.33	7,709.41	4,422.26
Share ratio	24.68%	20.07%	12.04%	7.86%	4.51%
Consumption ratio	100.00%	81.34%	48.78%	31.85%	18.27%
Total consumption (m^3)	**98,096.54**	**32,275.15**	**21,884.10**	**15,211.20**	**9,170.28**
Consumption ratio	100.00%	32.90%	22.31%	15.51%	9.35%
Total water cost (EGP)	647,437.17	213,015.96	144,435.05	100,393.91	60,523.82

(6.60 EGP per 1 m^3 of desalinated water)

Table 67 Proposed yearly water-efficient scenarios by indoor sectors in Resta grand resort, Marsa Alam **(Researcher)**

Resort sectors	Existing	Baseline	Basic	Intermediate	Advanced
Guestrooms	145,936.00	12,895.87	11,078.40	8,034.42	5,614.24
Share ratio	62.63%	5.53%	4.75%	3.45%	2.41%
Consumption ratio	100.00%	8.84%	7.59%	5.51%	3.85%
Kitchen	5,811.00	6,273.55	4,917.67	3,121.95	1,896.15
Share ratio	2.49%	2.69%	2.11%	1.34%	0.81%
Consumption ratio	100.00%	107.96%	84.63%	53.72%	32.63%
Laundry	17,719.00	28,060.68	20,275.06	15,206.29	9,123.78
Share ratio	7.60%	12.04%	8.70%	6.53%	3.92%
Consumption ratio	100.00%	158.36%	114.43%	85.82%	51.49%
Public	40,341.00	41,272.48	40,034.40	29,833.21	19,514.66
Share ratio	17.31%	17.71%	17.18%	12.80%	8.38%
Consumption ratio	100.00%	102.31%	99.24%	73.95%	48.37%
Staff	23,200.00	27,535.57	17,654.52	11,851.39	7,855.92
Share ratio	9.96%	11.82%	7.58%	5.09%	3.37%
Consumption ratio	100.00%	118.69%	76.10%	51.08%	33.86%
Total consumption (m^3)	**233,007.00**	**116,038.16**	**93,960.04**	**68,047.26**	**44,004.75**
Consumption ratio	100.00%	49.80%	40.32%	29.20%	18.89%
Total water cost (EGP)	1,537,846.20	765,851.87	620,136.29	449,111.91	290,431.33

(6.60 EGP per 1 m^3 of desalinated water)

Table 68 Proposed yearly water-efficient scenarios by indoor sectors in Hilton Sharm Dreams resort, Sharm El-Sheikh **(Researcher)**

Resort sectors	Existing	Baseline	Basic	Intermediate	Advanced
Guestrooms	60,935.00	12,613.42	10,835.75	7,858.44	5,491.28
Share ratio	37.81%	7.83%	6.72%	4.88%	3.41%
Consumption ratio	100.00%	20.70%	17.78%	12.90%	9.01%
Kitchen	8,721.00	3,272.29	2,595.61	1,757.01	873.21
Share ratio	5.41%	2.03%	1.61%	1.09%	0.54%
Consumption ratio	100.00%	37.52%	29.76%	20.15%	10.01%
Laundry	11,712.00	7,165.24	5,177.20	3,882.90	2,329.74
Share ratio	7.27%	4.45%	3.21%	2.41%	1.45%
Consumption ratio	100.00%	61.18%	44.20%	33.15%	19.89%
Public	22,680.00	15,404.76	15,046.38	11,253.26	7,470.02
Share ratio	14.07%	9.56%	9.34%	6.98%	4.64%
Consumption ratio	100.00%	67.92%	66.34%	49.62%	32.94%
Staff	57,107.00	11,973.82	7,564.08	5,077.36	2,711.12
Share ratio	35.44%	7.43%	4.69%	3.15%	1.68%
Consumption ratio	100.00%	20.97%	13.25%	8.89%	4.75%
Total consumption (m^3)	**161,155.00**	**50,429.54**	**41,219.03**	**29,828.97**	**18,875.37**
Consumption ratio	100.00%	31.29%	25.58%	18.51%	11.71%
Total water cost (EGP)	1,063,623.00	332,834.99	272,045.57	196,871.20	124,577.43

(6.60 EGP per 1 m^3 of desalinated water)

Table 69 Proposed yearly water-efficient scenarios by indoor sectors in Movenpick Naama Bay resort, Sharm El-Sheikh **(Researcher)**

Resort sectors	Existing	Baseline	Basic	Intermediate	Advanced
Guestrooms	35,929.05	31,379.31	26,956.88	19,550.01	13,661.04
Share ratio	33.72%	29.45%	25.30%	18.35%	12.82%
Consumption ratio	100.00%	87.34%	75.03%	54.41%	38.02%
Kitchen	10,119.89	10,039.50	7,826.76	4,994.92	2,972.11
Share ratio	9.50%	9.42%	7.35%	4.69%	2.79%
Consumption ratio	100.00%	99.21%	77.34%	49.36%	29.37%
Laundry	16,316.74	12,227.73	8,835.07	6,626.30	3,975.78
Share ratio	15.31%	11.48%	8.29%	6.22%	3.73%
Consumption ratio	100.00%	74.94%	54.15%	40.61%	24.37%
Public	13,327.11	15,792.28	14,068.29	10,319.66	6,383.37
Share ratio	12.51%	14.82%	13.20%	9.68%	5.99%
Consumption ratio	100.00%	118.50%	105.56%	77.43%	47.90%
Staff	30,866.17	22,002.18	13,880.50	9,212.27	5,773.95
Share ratio	28.97%	20.65%	13.03%	8.65%	5.42%
Consumption ratio	100.00%	71.28%	44.97%	29.85%	18.71%
Total consumption (m^3)	**106,558.95**	**91,441.01**	**71,567.50**	**50,703.17**	**32,766.26**
Consumption ratio	100.00%	85.81%	67.16%	47.58%	30.75%
Total water cost (EGP)	703,289.07	603,510.69	472,345.49	334,640.89	216,257.28

(6.60 EGP per 1 m^3 of desalinated water)

Table 70 Proposed yearly water-efficient scenarios by indoor sectors in Hilton Taba & Nelson Village resort, Taba **(Researcher)**

Resort sectors	Existing	Baseline	Basic	Intermediate	Advanced
Guestrooms	36,698.60	33,634.27	28,894.03	20,954.90	14,642.74
Share ratio	30.16%	27.64%	23.74%	17.22%	12.03%
Consumption ratio	100.00%	91.65%	78.73%	57.10%	39.90%
Kitchen	11,322.05	11,449.03	8,950.27	5,709.28	3,396.72
Share ratio	9.30%	9.41%	7.35%	4.69%	2.79%
Consumption ratio	100.00%	101.12%	79.05%	50.43%	30.00%
Laundry	17,295.75	12,961.40	9,365.17	7,023.88	4,214.33
Share ratio	14.21%	10.65%	7.70%	5.77%	3.46%
Consumption ratio	100.00%	74.94%	54.15%	40.61%	24.37%
Public	18,186.17	20,191.71	18,262.92	13,434.11	8,388.01
Share ratio	14.94%	16.59%	15.01%	11.04%	6.89%
Consumption ratio	100.00%	111.03%	100.42%	73.87%	46.12%
Staff	38,196.88	18,299.93	11,542.53	7,649.19	4,792.94
Share ratio	31.39%	15.04%	9.48%	6.29%	3.94%
Consumption ratio	100.00%	47.91%	30.22%	20.03%	12.55%
Total consumption (m^3)	**121,699.45**	**96,536.33**	**77,014.91**	**54,771.36**	**35,434.75**
Consumption ratio	100.00%	79.32%	63.28%	45.01%	29.12%
Total water cost (EGP)	803,216.37	637,139.76	508,298.43	361,490.99	233,869.33

(6.60 EGP per 1 m^3 of desalinated water)

Table 71 Proposed yearly water-efficient scenarios by indoor sectors in Movenpick Taba resort, Taba **(Researcher)**

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Arabic abstract

المستخلص

ان زيادة الوعي بالمعدل المتسارع لنضوب الموارد المائية يؤدي الى زيادة الحاجة الى المنشآت ذات الكفاءة المائية. حاليا يعتبر 35% من الاستخدام الآدمي للمياه استخداما غير مستدام، اعتمادا على تناقص مياه الخزانات الجوفية وانخفاض سريان الأنهار الرئيسية. هذه النسبة من المرجح زيادتها إذا ساءت التغيرات المناخية خاصة "الاحتباس الحراري"، وزيادة النمو السكاني، والنفاذ التدريجي للموارد وتلوث المصادر بشكل غير صحي.

يعتبر اقليم البحر الأحمر أحد المناطق السياحية الواعدة التي تواجه نقصا في المياه بمصر بالرغم من أن خطط تنميته اقتصاديا وسياحيا تعتمد بالأساس على توافر المياه. اقليم البحر الأحمر يتسم بعدم وجود مصادر للمياه السطحية، ومواسم هطول أمطار على المرتفعات بمعدلات منخفضة، ومياه خزانات جوفية ساحلية عالية الملوحة. ان الاستخدام المستدام للمياه يقصد الى الحفاظ على الموارد والمواءمة البيئية والملاءمة التكنولوجية والنمو الاقتصادي والقبول المجتمعي لقضايا التنمية، حيث يشمل الابتكار تكيف الخبرة التقليدية مع التحديات الراهنة، وتكيف التكنولوجيات المتاحة خارجيا مع الأحوال المادية والاجتماعية السائدة.

لمراحل تصميم وتشييد وتشغيل المنشآت تأثير قوي على بيئتنا ومواردنا الطبيعية، في حين تعمل ممارسات التشغيل الخضراء على تقليل استخدام الموارد وتلوثها مع زيادة القيمة المستمدة من كل مورد مستخدم. تعتبر ممارسات تشغيل المنشأ من كبار المستهلكين للمياه. يمكن اجراء العديد من القرارات الهامة المتعلقة بالمنشآت ذات الكفاءة المائية أثناء عملية التشغيل، ومن هذه القرارات الهامة استخدام تقنيات مرشدة للمياه الصالحة للشرب، والاعتماد على طرق معالجة مياه الصرف، والاستفادة من تطبيقات المياه الغير صالحة للشرب. يجب أن يعتمد اختيار ممارسات رفع الكفاءة المائية على متطلبات التصميم والتنفيذ، والتكيف مع الظروف المناخية، وتحقيق كل من ترشيد المياه والاستمرارية والتكاليف الأولية المناسبة.

في هذه البحث، تم دراسة مختلف التقنيات المرشدة للمياه والتي يمكن استخدامها في اقليم البحر الأحمر بمصر. فأولا تم تصنيف جميع التقنيات التي تم مناقشتها اعتمادا على نوع المياه المستخدمة (صالحة للشرب أو غير صالحة للشرب). ثم تحليل استهلاك المياه في جميع القطاعات الوظيفية الداخلية للمنتجعات المختارة كدراسات حالة على طول ساحل البحر الأحمر. وأخيرا الخلوص الى تصنيف مختلف التقنيات ذات الكفاءة المائية التي يمكن استخدامها أثناء تشغيل منتجع. كما يحدد أيضا القرارات ذات الصلة المتخذة من المعماريين لاختيار التقنيات ذات الكفاءة المائية المناسبة خلال عمليات تصميم وتشييد منتجع سياحي في اقليم البحر الأحمر.

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يونيو 2013م.

اقرار

هذه الرسالة مقدمة الى كلية الهندسة بجامعة عين شمس كجزء من متطلبات الحصول على درجة الماجستير في الهندسة المعمارية.

تم اجراء هذه الرسالة بمعرفة الباحث في قسم الهندسة المعمارية بكلية الهندسة جامعة عين شمس في الفترة الواقعة بين أبريل 2011 حتى يونيو 2013.

هذا ولن يقدم هذا البحث او اي جزء منه لنيل أي مؤهل او درجة علمية من أي كلية او معهد علمي اخر.

وهذا اقرار منى بذلك،

الاسم: أحمد خالد محمد عبد الحميد

التوقيع:

التاريخ: 2013/6/18

جامـــعة عــين شــمس
كلــــية الهـــــــندسة
قسم الهندسة المعمارية

عنوان الرسالة: دراسة رفع الكفاءة المائية لمنتجعات البحر الأحمر المصرية

(تقنيات المياه و تأثيرها على الاستهلاك الأمثل في مرحلة التشغيل)

اسم الباحث: أحمد خالد محمد عبد الحميد
معيد بقسم الهندسة المعمارية - كلية الهندسة - جامعة عين شمس

لجنة الحكم

السيد الاستاذ الدكتور/ أحمد رضا عابدين ____________________
استاذ العمارة بقسم الهندسة المعمارية
كلية الهندسة - جامعة القاهرة

السيد الاستاذ الدكتور/ ياسر محمد منصور ____________________
استاذ العمارة بقسم الهندسة المعمارية
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السيد الاستاذ الدكتور/ سيد مدبولي علي ____________________
استاذ العمارة بقسم الهندسة المعمارية
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السيد الدكتور/ أحمد عاطف فجال ____________________
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تاريخ البحث
الدراسات العليا
ختم الاجازة:
اجيزت الرسالة بتاريخ : / /
موافقة مجلس الكلية ، موافقة مجلس الجامعة
/ / / /

جامــعة عــين شــمس
كلـــية الهـــــندسة
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(تقنيات المياه و تأثيرها على الاستهلاك الأمثل في مرحلة التشغيل)

مقدمة من
م. أحمد خالد محمد عبد الحميد
بكالوريوس الهندسة المعمارية - جامعة عين شمس 2009

رسالة مقدمة لنيل

درجة ماجستير العلوم في الهندسة المعمارية

تحت اشراف:

أ.د. سيد مدبولي علي
أستاذ بقسم الهندسة المعمارية
كلية الهندسة - جامعة عين شمس

أ.م.د. أحمد عاطف فجال
أستاذ مساعد بقسم الهندسة المعمارية
كلية الهندسة - جامعة عين شمس

جامعة عين شمس
2013