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GROUNDWATER, KEY TO THE SUSTAINABLE DEVELOPMENT GOALS (SDGs)

# CLIMATE CHANGE AND WATER RESOURCES IN THE BAHAMAS
## Use of the reverse geothermal conditions of the groundwater, toward adaptation measures

### The Bahamas

Officially The Commonwealth of the Bahamas, The Bahamas encompasses a total land area of 31,810 square kilometers (12,281 square miles); scattered over 250,102 square kilometers (96,564 square miles), with a total coastline of 3,542 kilometers (2,200 miles) and water area of 218,292 square kilometers (84,283 square miles).

The urban sector in The Bahamas comprises the major population centers of New Providence & Grand Bahama Island, totaling 85% of the population. The rural describes all the other population centers of the Commonwealth. The provision of affordable water and energy is presently a concern throughout the Islands of The Bahamas.

The effects of climate change shall continue to exacerbate the concerns of both water and energy supply, and the effective development of the rural population centers. (See Figure I. below for Map of The Bahamas – Bahamas Water Resources Reports, Credit: 2009 Ezilon.com).

**Figure I. - Map of the Islands of The Commonwealth of the Bahamas**


### Water Resources of The Bahamas

The groundwater resources of the Commonwealth comprise the fresh, brackish, saline and hyper saline waters found in the near and deep subsurface and in the lakes and ponds that intercept the surface. The freshwater resources occur as three-dimensional lens-shaped bodies, which overlies brackish and saline waters at depth.

It is inappropriate to conceive of these Ghyben-Hertzberg lenses as occurring in subterranean lakes, rivers or ponds. In excess of ninety percent (90%) of the freshwater lenses are within 1.52-meters (5-feet) of the surface. (See Figure II. below for Freshwater Lens in The Bahamas – J. Bowleg, 2002).

**Figure II. – Diagram of Ghyben-Hertzberg Lens**

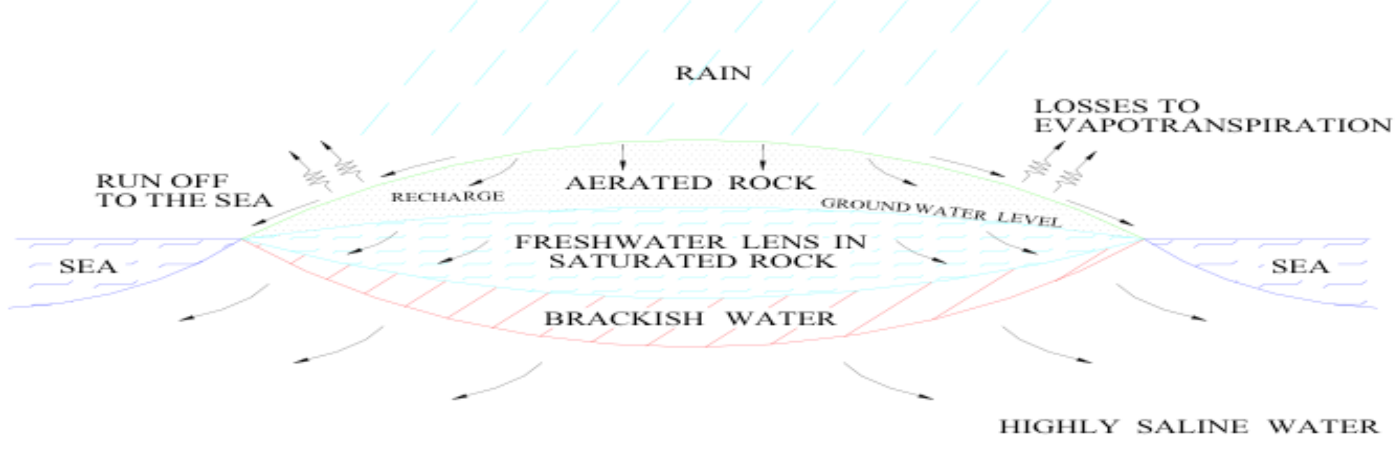



Diagram of a Freshwater Lens in an Oceanic Island (Like The Bahamas)

The quantified freshwater resources of The Bahamas can best be described as being limited. Thus, the provision of water supply is heavily sustained by means of seawater reverse osmosis (**SWRO**). Being the single source of freshwater for The Bahamas, the groundwater resources should be considered as a strategic national resource.

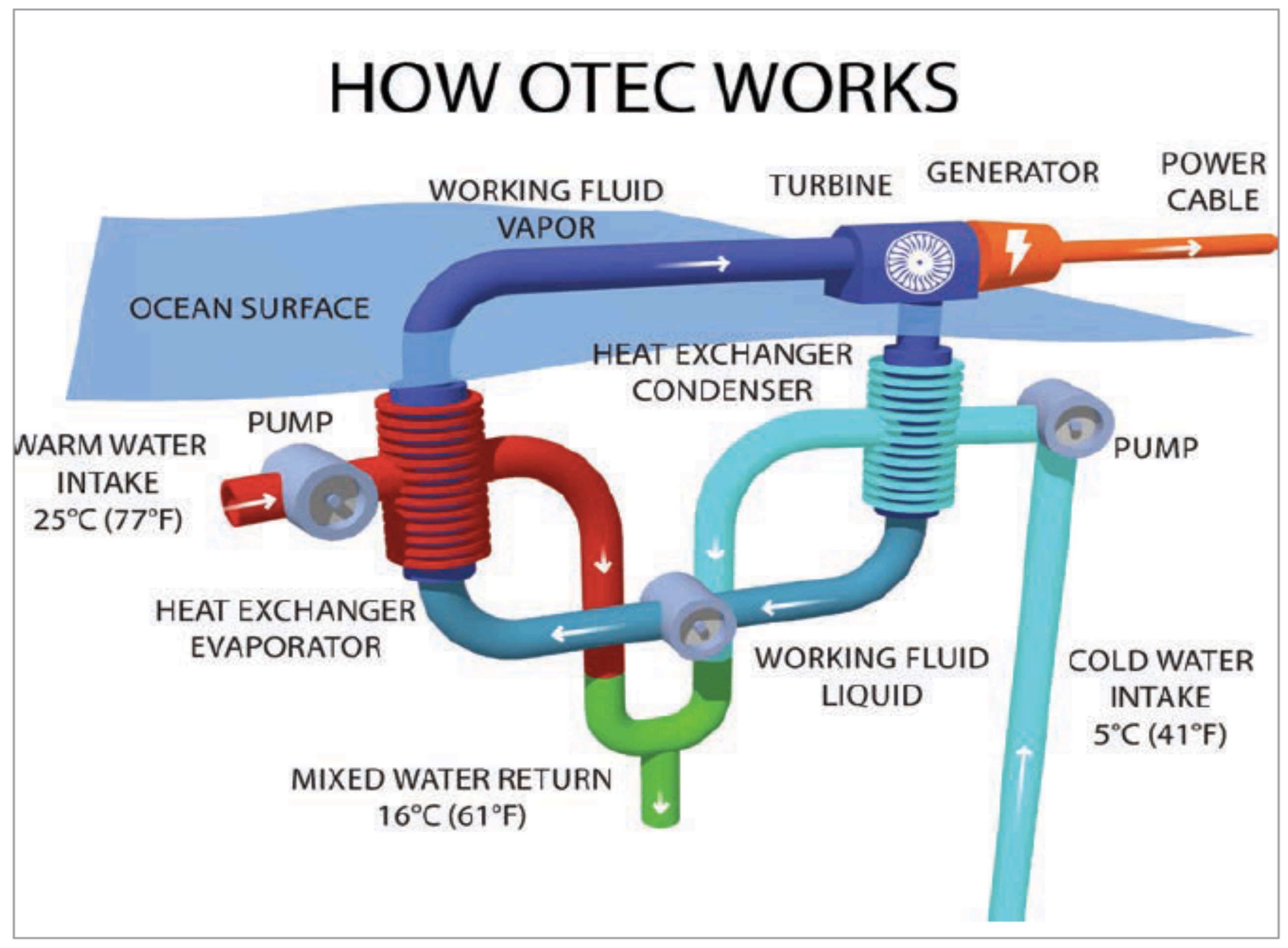
**What is specifically unique of the water resources of The Bahamas is the existence of the subsurface inverted geothermal conditions - readily available supply of cold seawater at depth, below the fresh groundwater lens.**

### Potential Use of Inverted Geothermal Conditions of the Groundwater

According to drilling logs throughout The Bahamas, there are several cavernous zones underlying the Lucayan Limestone. The cavernous zones are highly transmissive and hydraulically suited for both the abstraction of cold seawater, and the effective return of seawater flows.

**SWRO** in the Bahamas presently utilizes groundwater supply and discharge wells, as direct abstraction and discharge to the marine environment is not permitted. Ocean Thermal Energy Conversion (**OTEC**) is a sustainable application that has been explored, using the temperature differential of the cooler deep and warmer surface seawater to run a heat engine. (See Figure III. below for a typical **OTEC** Process, Credit: Makai Ocean Engineering Inc.). The **OTEC** Technology output is primarily limited by the amount of water that can be pumped (See Figure IV. below).

**Figure III. Diagram of How the OTEC Process Works**




*A "closed" OTEC cycle uses warm seawater to evaporate ammonia and cold seawater to condense it again. The vapor moving from higher to lower pressure spins a turbine, generating electricity. Credit: Makai Ocean Engineering Inc.*

### Water-Energy Nexus for The Bahamas – OTEC Prospective

**Thru the integration of OTEC with the SWRO technologies, it is anticipated to possibly attend to key climate resilience goals of The Bahamas: SDG#6 - Clean Water & Sanitation, along with SDG#7 - Affordable & Clean Energy [Renewable Energy Systems].**

A minimum **OTEC** temperature differential of 20$^{o}$C (36$^{o}$F) is required between the hot and cold source; the average surface source water from shallow wells is 27$^{o}$C (81$^{o}$F) - the desired **OTEC** cold water source would be 7$^{o}$C (45$^{o}$F). The **OTEC** minimum required hot source (per existing readily available cold) is 45$^{o}$C (113$^{o}$F). Hydraulic conductivities at depth further support the effort.

**Figure IV. Typical Hydraulic Conductivity Readings for The Bahamas**

| Sample Depth | Typical Vertical Hydraulic Conductivity | | Porosity |
|---|---|---|---|
| (ft bls) \| (m bls) | (cm/sec) | (ft/day) | (%) |
| 80 \| 24.4 | 2.0E-06 | 5.7E-03 | 12.1 |
| 200 \| 61.0 | 1.4E-05 | 4.0E-02 | 9.2 |
| 500 \| 152.4 | 2.8E-05 | 7.9E-02 | 6.7 |
| 550 \| 167.6 | 1.4E-08 | 4.9E-05 | 6.3 |
| 600 \| 182.9 | 2.4E-04 | 6.8E-01 | 7.9 |

Note: bls = below land surface

Desired 54,510-m$^{3}$/Day (10,000-GPM) @ 24$^{o}$C to 25$^{o}$C (75$^{o}$F to 78$^{o}$F) from two to three boreholes with an adjustment to the high temperature source water of the **OTEC**, by Solar Photovoltaic Cells to 50$^{o}$C (122$^{o}$F) has been proposed for commencement of an **OTEC** Pilot Project. A small capacity **OTEC** Generator can initially run the distribution and/or high-pressure pumps of the **SWRO**.

**A projected 914.4-meter (3,000-foot) test well has been proposed for the full potential of the OTEC Technology in The Bahamas – depth for the 7$^{o}$C (45$^{o}$F) cold seawater supply source.**