Excerpts from:

Global Warming: Effect, Solution, Opportunity

By Carl N. Hodges

Seawater Farms Bahia Kino (SFBK) Mexico will be 500,000 hectares of integrated aquaculture and agriculture irrigated with seawater to produce SeaForest BioFuels™ and other products. The Seawater River of SFBK and those of 49 associated projects will flow seawater inland in quantity to stop sea level rise.

Technologies presented within are Patent Pending
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7 June 2007

The Seawater Foundation Presents a Program That:

1. Introduces SeaForest BioFuels™ (Including SeaForest BioDiesel-10™)

2. Creates Wealth and Jobs

3. Provides Increased Quantities of Fresh Water

4. Offers Biodiversity Enhancement and Resulting Business Opportunities

5. Removes CO_2 from the Atmosphere at a Scale to Contribute to Reducing Global Warming

6. Stops Sea Level Rise

Ten Advantages of SeaForest BioDiesel-10™

Seawater agriculture SeaForest BioDiesel-10™:

1. is viable now and potentially the most profitable of liquid biofuel alternatives.

2. uses the effectively infinite source of seawater, and does not compete for limited fresh water.

3. is not land constrained and capable of making more than 300 million hectares of coastal area highly productive in ecologically enhancing ways.

4. is not competitive with existing needs for rain-fed or freshwater-irrigated agricultural land for conventional animal and human food production. The worldwide problem of escalating food prices is solved.

5. utilizes effluent nutrients from aquatic seawater farm animals for plant production.

6. distributes new wealth worldwide to where it is urgently needed thereby reducing migration pressures.

7. removes from the atmosphere 10 times the amount of carbon, through its integrated production process, the amount of carbon it returns to the atmosphere when used.

8. creates soil by bringing seawater and nutrients from the sea to land for photosynthesis.

9. provides new sources of fresh water by seawater substitution for current freshwater uses and seawater serves as a "seawater base" of new lenses of fresh water.

10. addresses sea level rise directly by removing seawater from the ocean ultimately at a rate to stop sea level rise (SLR).

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GLOBAL WARMING: EFFECT, SOLUTION, OPPORTUNITY
Selected Excerpts…

Stopping Sea Level Rise

The development of Integrated Seawater Farms provides a solution to a major effect of global warming, sea level rise (SLR). Implementation of the SLR solution and future expansion of Integrated Seawater Farms by a factor of ten, with participation of many "partners," becomes a key component of a grander, long-term, complex but achievable solution to the problem of global warming itself.

Based on research and development of more than 30 years of work by the Environmental Research Laboratory (ERL) of the University of Arizona and The Seawater Foundation, we now have the science, technology, history, and means to create Integrated Seawater Farms along seawater rivers flowing inland from the sea along the 350,000 kilometers of the world's coastlines. In the majority of cases these seawater farms will be inland along seawater rivers originating at the world's 40,000 kilometers of desert seacoasts. However, there are circumstances in non-desert countries where the combination of need for wealth generation and the need to address problems of over-exploited freshwater resources will make non-desert coasts the origin of inland flowing seawater rivers.

Work during the first 25 years of the 30 years referenced above did not have a principal focus on the contribution of this technology to *stopping* SLR. Given recent challenges to island nations, and the tragedy that occurred in New Orleans from Hurricane Katrina and other SLR challenges, it is clear the capability to immediately slow and within ten years stop SLR becomes a highly important, if not dominant, consideration for implementation. The Seawater Farms technology is best quickly reviewed by viewing the video "The Greening of Eritrea."

Beginning in the late 1960s, changes in the world climate became a concern. By the mid-1970s, this concern was being articulated in terms of climate's effect on the earth's temperature, our ability to produce food, and impacts on biological and political systems. The latter was addressed in Europe by Sir Crispin Tickell in his "Climate Change on World Affairs" in 1977, (Ref. 1), and in the U.S. by Dr. Walter Orr Roberts and Henry Lansford in the 1979 publication, "The Climate Mandate," (Ref. 2).

Following those important publications, the National Center for Atmospheric Research (NCAR) in Boulder, Colorado, the Aspen Institute, and others

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convened seminars, and papers were written on the likelihood of serious effects from the earth's warming as a result of increases in the carbon dioxide level of the atmosphere. This increase was due to two factors, the accelerating use of fossil fuels putting carbon dioxide into the air, and the denuding of the earth by deforesting, overgrazing, desertification, etc., reducing the earth's ability to remove CO_2 from the atmosphere by photosynthesis of green plants.

In 1980, the American Association for the Advancement of Science held a seminar at its annual meeting, sponsored by the then newly established AAAS climate project. This resulted in the 1981 book, *Climate's Impact on Food Supplies: Strategies and Technologies for Climate-Defensive Food Production*. Three selections from that book are available on the Seawater Foundation website: The Introduction by Dr. Walter Orr Roberts; Chapter 3, "Uses of Climatic Knowledge in the Food Systems of Developing Countries," by Dr. Roger Revelle; and Chapter 11, "New Options for Climate-Defensive Food Production."

In 1990, a paper by Thomas Goreau in *AMBIO* magazine, "Balancing Atmospheric Carbon Dioxide," provided an analysis to show the world

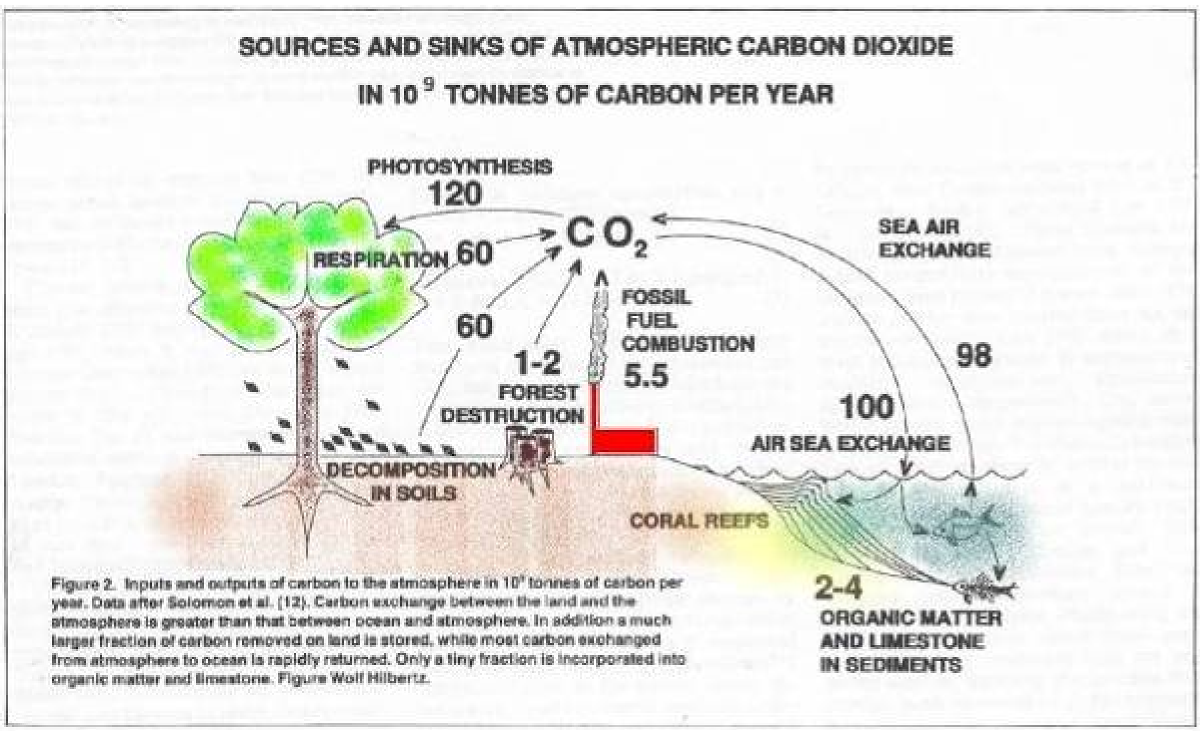

Figure 1. From *AMBIO* magazine 1990 - Thomas Goreau, "Balancing Atmospheric Carbon Dioxide," Source and Sinks of Atmospheric Carbon Dioxide in 10^9 Tonnes of Carbon per year.

needed 200 million plus hectares of new green to remove carbon dioxide from the air and permanently store it. Figure 1 here is also Figure 2 in Goreau's paper. Figure 1 shows carbon into the atmosphere from fossil fuel as 5.5 billion metric tons per year, like

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from 1987 data. Seventeen years later in 2004, the number is 7.4 billion metric tons per year, and the Electric Power Research Institute (EPRI) of the U.S. projects a doubling by 2050 with current approaches. We cannot let this happen.

The same year as Goreau's paper (1990), EPRI funded research at ERL for seawater-irrigated greenery to be of a scale to provide carbon fixation from the atmosphere while providing solid biofuels to address the problem. This work included a worldwide review of areas of potential benefit from seawater agriculture (Attachment 4).

A 1993 *AMBIO* paper, "Reversing the Flow: Water and Nutrients from the Sea to the Land," from ERL reviews the state of seawater agriculture and its applications to that time.

Solutions

Here The Seawater Foundation proposes that, in the next ten years, 25 million hectares of new seawater-irrigated land be developed with seawater supplied from seawater rivers running from the seacoast inland.

It merits stating that these areas of new green will not consume the beaches of the world. Beachfronts have potentially higher economic value use for communities, resorts, ecological preserves, etc. A dramatic example is the Ala Wai (seawater) Canal coming inland and behind Waikiki in Honolulu, Hawaii (Figure 2).

Figure 2. The Ala Wai (seawater) Canal coming inland and behind Waikiki in Honolulu, Hawaii.

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Figure 3. Artist's concept of Integrated Seawater Farms using shrimp farm effluent between Bahia Kino and Guaymas, Sonora, Mexico.

These first seawater farms should be located in regions selected for maximum capability of permanently removing seawater from the oceans.

Fifty seawater farms, each of 500,000 hectares, will have the capability to permanently remove from the sea enough seawater to stop SLR. That is, the seawater farms will continuously pump and permanently remove seawater from the oceans at a rate greater than the rate at which oceans are rising due to ice melt, thermal expansion, the flow of a fraction of pumped groundwater that makes its way into the sea, and other causes.

The current effective volume of seawater increase causing SLR is 1,010 cubic kilometers of water per year (Figure 4). This is a large but pumpable amount of water. In fact, current world pumping of underground water is larger, 1,100 cubic kilometers per year (Figure 5).

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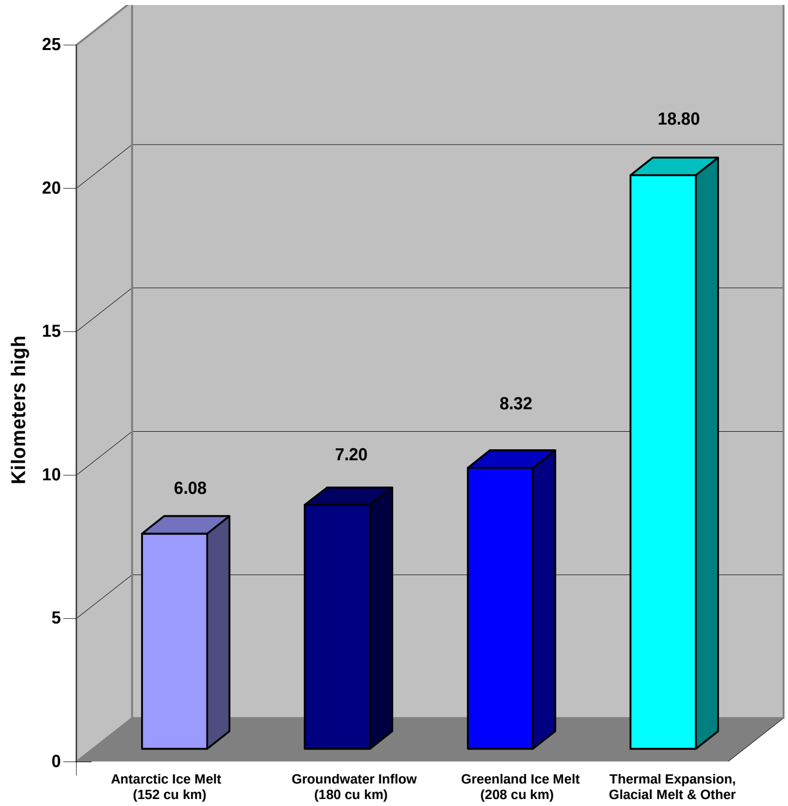

Figure 4. Water Volume Equivalent Contributing to Sea Level Rise (Shown as annual amounts in 25 sq km base water columns).

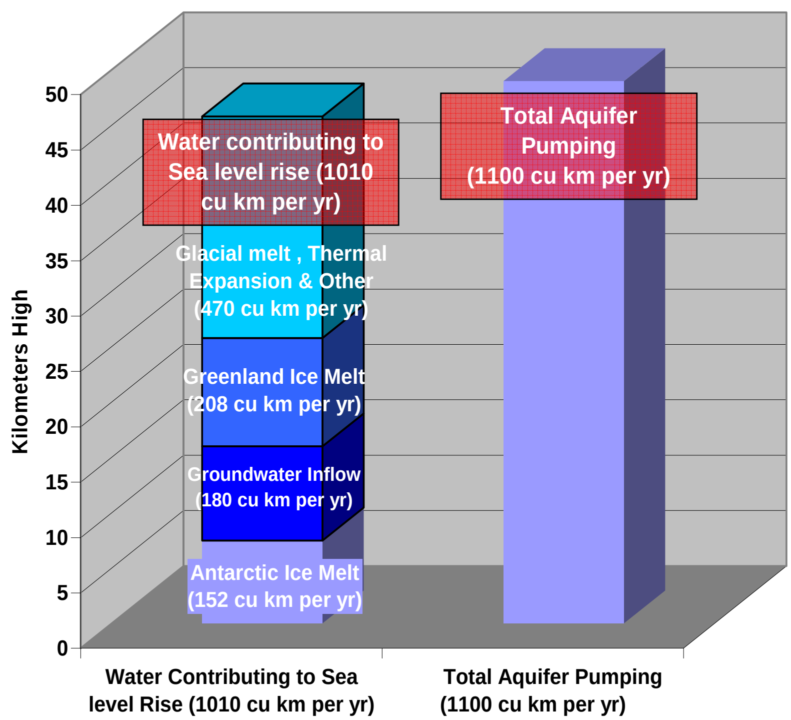

Figure 5. Water Volume Equivalent Contributing to Sea Level Rise Compared to Groundwater Pumping (Shown as annual amounts in 25 sq km base columns).

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Decades of over-pumping of coastal aquifers have lowered underground freshwater levels such that in numerous coastal areas seawater has encroached on freshwater supplies. Linked is a paper by Jose Marie Martinez, "Aquifers and Free Trade: An Hermosillo Coast Case Study," for this problem and opportunity of the coastal plain of Hermosillo, the site of Seawater Farms Bahia Kino, Sonora, Mexico.

The Foundation proposes to pump seawater from rivers coming inland from the sea onto the land. Initially, in the seawater rivers, the harvest of aquatic products removes seawater from the oceans. That is, shrimp, fish and aquatic plants contain water that came from the sea. As those products are marketed, water and nutrients from the sea are moved inland. This is a small but highly valued quantity of water from the sea. Water evaporated from the surface of the seawater rivers, canals, lakes, and created wetlands goes into the atmosphere and ultimately returns as rain. The majority of the rain from water evaporated from coastal land returns to the land as rain or snow due to orographic lifting. Water from the atmosphere increases soil moisture, snow pack and becomes part of the plant and animal freshwater biomass. Less than 20% returns to the sea.

Seawater used in irrigation, once onto the land, evaporates from the surface of the soil, transpires from the plants, and goes through the atmospheric cycle as above.

On-land, use and storage of seawater occur above ground in four ways: in seawater rivers and lakes, evaporated from water and land surfaces and transpired from plants, in products, and "on farm" standing biomass. Below ground seawater is stored in two ways: by the seawater irrigation raising the water content of soil between the surface and the new underground seawater aquifer up to field capacity (that is, all the water the soil will hold if completely provided with irrigation, which is normally something of the order of 20% water of the volume of soil in that space), and stored in a new seawater aquifer created by the seawater irrigation of the surface. This aquifer is in the space between the edge of the sea and the inland most edge of seawater irrigation. The new seawater aquifer includes a new enlarged seawater base for the freshwater lens and the inland double seawater wedge below inland seawater rivers.

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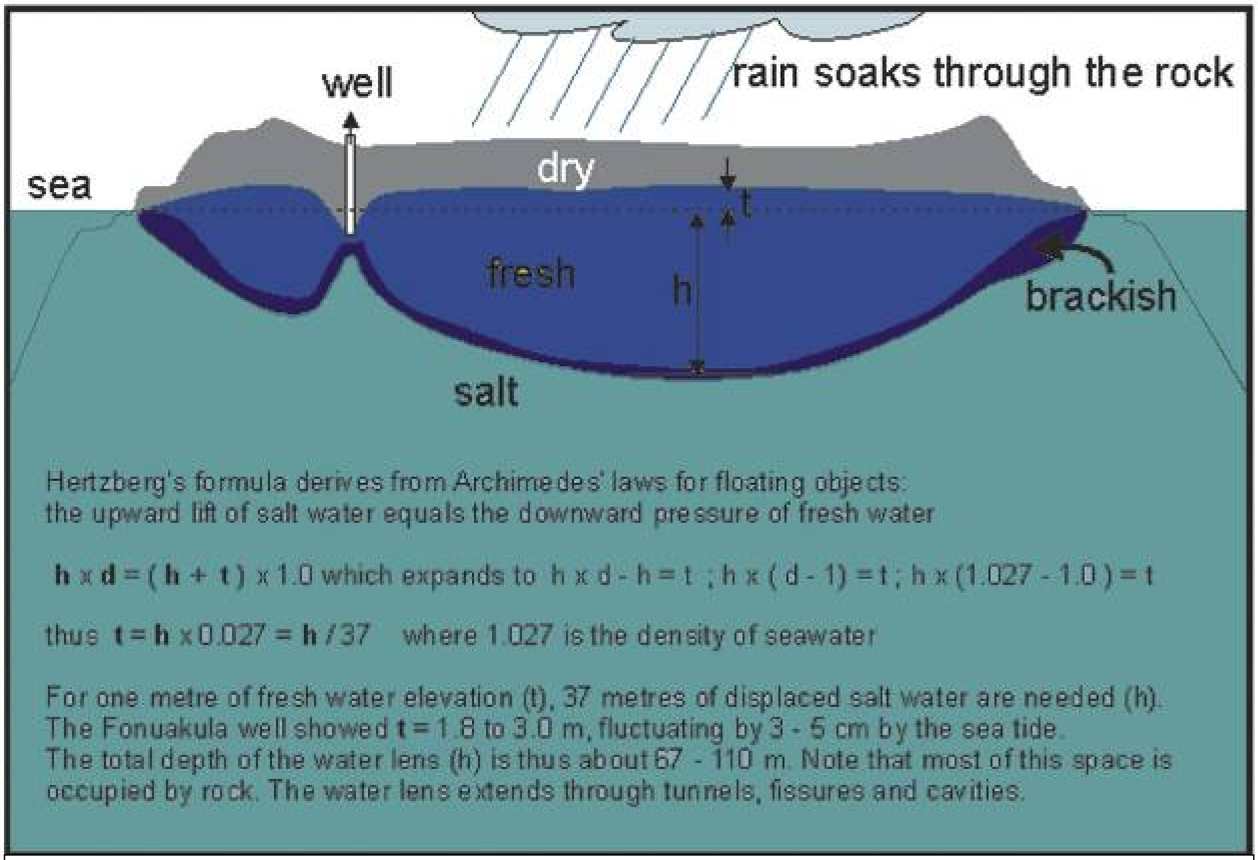
It is important to understand the magnitude and reality of the storage area for seawater.

Seawater is heavier than freshwater. Freshwater weighs 62.4 pounds per cubic feet and seawater weighs 64.2 pounds per cubic feet, or the scientific way to say this is seawater has a density of 1.027 times that of freshwater.

Figure 6. illustrates inland freshwater lens for the island



A dug well at Fonuakula is 54.3m deep, supplying water to the Tufukia hospital near Alofi. Its shaft is 1.5x1.2m wide, bored through the massive limestone. It can sustain 400 gallons/hr (1800l/h). At 2m of rainfall per year, the input to the water lens is 500 billion litres or 500 million cubic metres (5.0E11). The water lens consists mainly of limestone with small pores.

Assuming an average depth of 50m, and a limestone porosity of 1%, the water lens may contain some 120 billion litres (120 million cubic metres) of fresh water.

Obviously, this water lens cannot grow any bigger, and all rain water flows off it to the sea above sea level. It is fascinating to see the many wells of fresh water spouting their contents over the clear sea water after a heavy rainfall.

Source: Geography and geology of Niue http://www.seafriends.org.nz/niue/geo.htm

Figure 6 presents an example for which empirical data has been provided of a freshwater lens floating on seawater under an island. Extensive information is available for the islands of Hawaii and other areas (Ref. 3).

The freshwater lens is created by either rain, as shown in the Niue diagram, or by water flowing towards the sea subsurface from rain that occurred

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further inland. The second term is often the dominant one along desert coastal areas.

Figure 7a presents the seawater wedge and scavenger well as tools to maintain a seawater-freshwater interface.

Scavenger wells usually pump brackish water to the sea. In our case, the scavenger well pumps brackish water from the freshwater side of a seawater wedge to irrigate Seawater Forests immediately seaward of a seawater river running parallel to the coast.

It is also possible that the petroleum industry will be able to provide innovations in this area with techniques such as 7c.

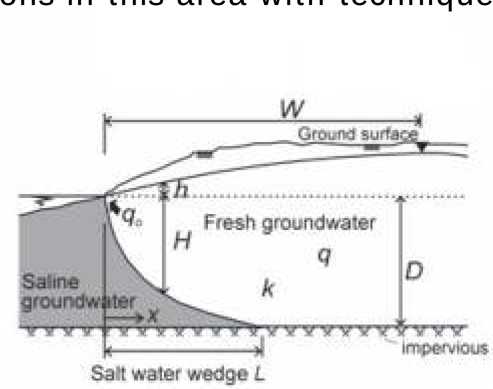

Figure 7a. Seawater wedge in a coastal aquifer

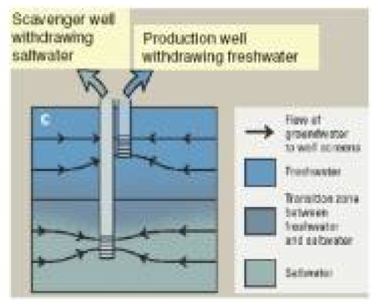

Figure 7b. Scavenger well inland of created seawater wedge

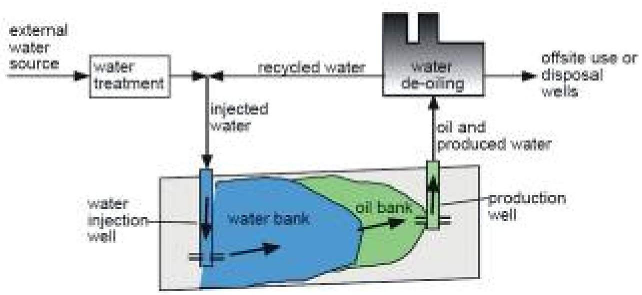

Figure 7c. Typical water Cycle in Oilfield Waterflood Operation

Figure 7. Movement and maintanence of Seawater Wedge

As the seawater irrigation starts initially close to the sea, just inland of beach activities, the fresh water inland of the moving wedge is pumped out and inland.

In many cases, such as the Hermosillo coastal plain, extensive pumping of fresh water has lowered the freshwater aquifer below sea level, and there is already some inflow of seawater near the coast. The usual response to this problem throughout the world is to abandon farmland near the sea and move continuously inland.

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Instead of retreat, seawater irrigation offers the capability for an active positive response. By bringing two seawater rivers inland and turning both parallel to the coast to meet one another, it is possible to effectively create "coastal islands" in which the freshwater aquifer between the inland river and the sea has been isolated. That freshwater aquifer can be pumped at a designed rate consistent with the optimum economics to provide a flow (coming inland) by a freshwater tributary of the new reverse flow seawater rivers. Figure 3 shows these on a large-scale plan view.

Figure 8 provides a cross section of the above and below-ground seawater and freshwater flows.

Whereas, the pumping of the freshwater from the "created island" aquifer would normally be from a rapidly dropping water table, instead it will be from a freshwater table level maintained by the movement of the seawater wedges toward the pumps and a newly created seawater base under the fresh water.

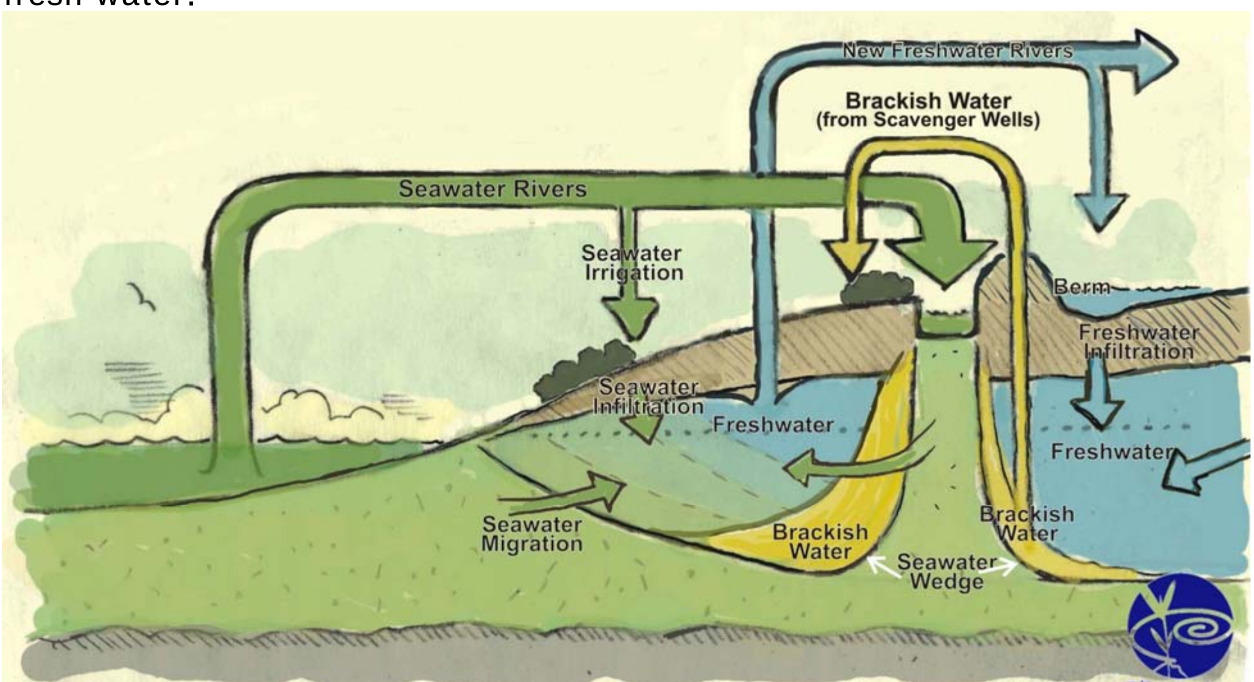

Figure 8. Seawater Rivers and the *Possibility* of Reverse Flow, Freshwater Tributaries

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As shown in Figure 8, the inland side of the seawater wedge is maintained by soil removed for the seawater river construction creating a berm for directing surface fresh water as shown. Second, a scavenger well is used to maintain the wedge inland and contribute to the wedge expansion on the coastal side of the seawater river.

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The quantity of fresh water that can be pumped inland is large. For Seawater Farms Bahia Kino, it is possible that a new freshwater source greater than the Central Arizona Project, 1.5 million acre-feet annually (60 m^3/sec) Figure 9, could be created.

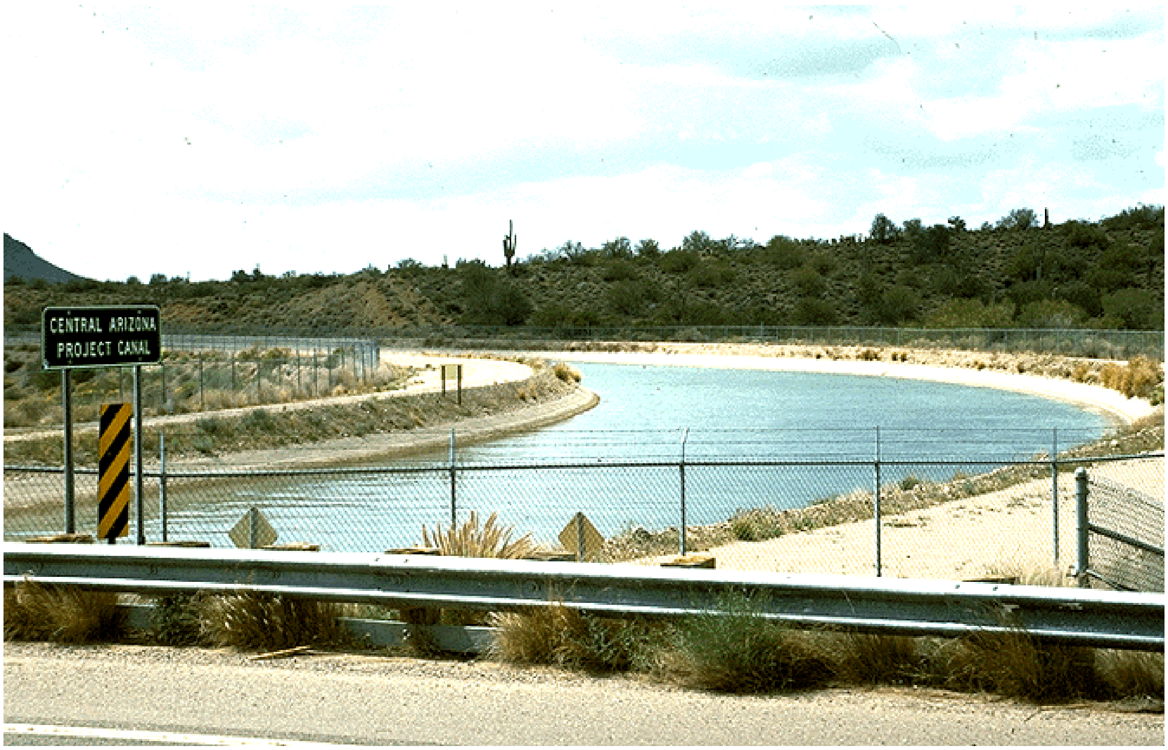

Figure 9. Central Arizona Project – 1.5 million acre feet per year. Provides water to 314,820 acres of irrigated agricultural land (a total of 127,000 hectares).

The seawater wedge can be brought inland distances up to 100 kilometers or more, depending on coastal topography and development considerations. For the coast of Sonora, it is likely this would be only to a maximum of 10 to 20 km for many decades. Seawater Farms Bahia Kino proposes a test of the possibility of new freshwater rivers from a 5 km by 5 km (25 km^2) area.

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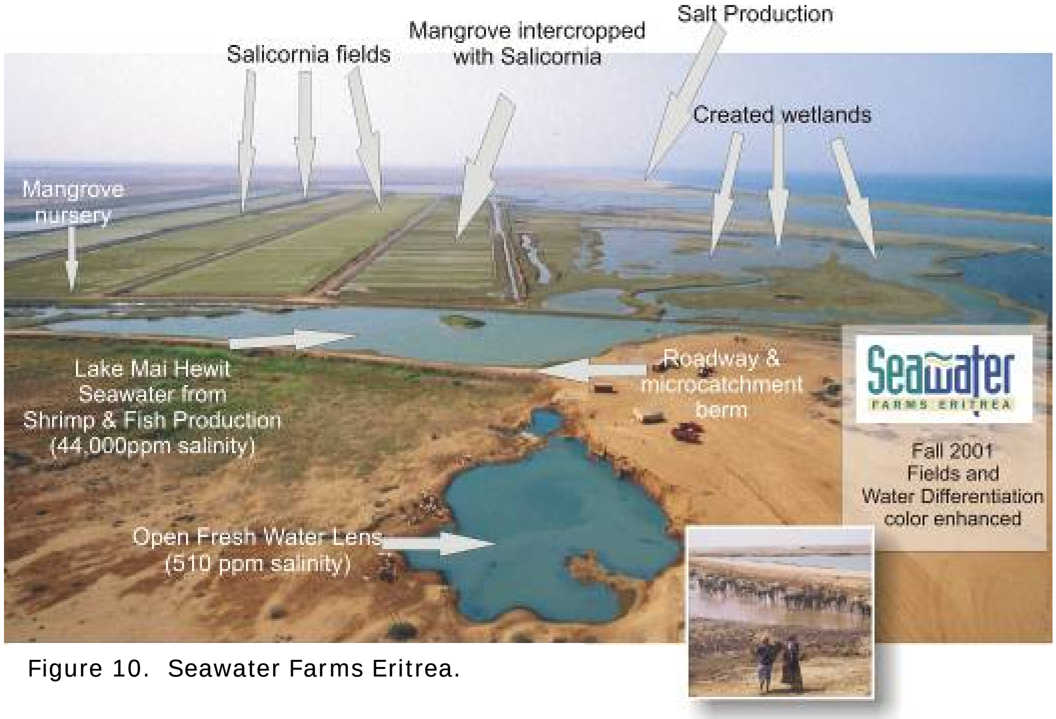

Figure 10. Seawater Farms Eritrea.

The volume of seawater utilized in products, evaporated into the atmosphere, but not returned to the sea through rain, and stored as soil moisture and seawater bases for fresh water, will be more than 70% of the seawater coming inland from the sea.

The amount of seawater stored in the soil and a new seawater aquifer can be accurately measured by the Gravity Recovery and Climate Experiment (GRACE) satellites. Please read "Grace in Space" from *Discovery* magazine. These are the satellites that measured the ice melt of the Antarctic and Arctic as reported in *Science* magazine's "Climate Change: Breaking the Ice", March 2006.

GRACE also measures an ice melt of 48.6 cubic kilometers per year from the State of Alaska. The amount of water to be pumped to each of the 50 seawater farms to stop SLR will be equal to 65% the ice melt of Alaska.

The GRACE satellites will be extremely valuable in determining the location of the future 49 seawater farms to stop SLR. In the words of Michael Watkins, Project Scientist for NASA's Jet Propulsion Laboratory,

> "…water can go underground, it can move around the ocean, it can change from ice to liquid and runoff, but it can't hide its mass from us…[Imagine a gigantic hockey puck made of water], it could be in the form of an ice sheet, or an aquifer, or a piece of ocean. GRACE has the sensitivity to pick up a puck about a

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> centimeter thick and 400 kilometers across. [All the water on Earth can be divided into hockey pucks, and GRACE takes note of how they move around every 30 days."

Each of the 50 seawater farms will move 20 "hockey pucks" of seawater from the sea onto the land every year. And, GRACE will keep track of them.

At six minutes and thirty seconds into the "The Greening of Eritrea" video, the narrator says:

> "Eventually, many weeks or months later, having been biologically cleaned as it is filtered through the ground, the seawater makes its way back to the Red Sea."

That is a true statement. No seawater returns to the sea except subsurface, and the seawater that does go subsurface has been both mechanically and biologically cleaned.

However, since the filming of the video (Spring 2003), we have changed the priority of our "benefits" focus, and now include designs to minimize subsurface flow back to the sea and maximize out of sea storage for stopping Sea Level Rise.

<u>SeaForest BioFuels™</u>

"New" uniquely desirable products are SeaForest BioFuel™. They can be considered "new" in that the world newly recognizes the need for biofuels. But, biofuels are old in concept. Rudolf Diesel proposed his diesel engine, invented in 1892, run on vegetable oil. In 1911 he wrote:

> "The use of vegetable oils for engine fuels may seem insignificant today, but such oils may become in the course of time as important as petroleum and coal tar products of the present."

The ERL 1981 AAAS paper proposed crops grown on seawater as future biofuels. The 1993 ERL-EPRI paper proposed solid fuels from halophytic plants.

And Figure 11 from the 1993 ERL *AMBIO* article suggests salicornia oil be blended with petroleum for a liquid fuel. And, Figure 12 is a 1992 test vehicle of The Seawater Foundation using salicornia oil.

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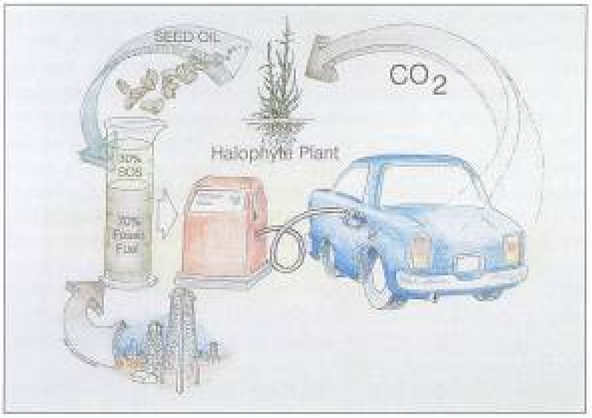
Figure 11. 1993 *AMBIO* paper.



Halophytes as a source of fuel for transportation.
Source: Environmental Research Laboratory.

Figure 12. Test vehicle running SeaForest BioDiesel-10™.

This paper proposes a new criterion for valuing biofuels by their System Atmospheric Carbon Benefits (SACB). For SeaForest BioDiesel-10™, this is expressed as the ratio of carbon removed from the atmosphere by the production system that produces the biofuel, divided by the carbon into the atmosphere from SeaForest BioDiesel-10™ use. This is done by the mangrove trees intercropped with salicornia as shown in Figure 13.

Other current biofuels have an SACB ranging from less than 1.0 to negative for corn-based ethanol to just less than 2.0 for soybean biodiesel.

When SeaForest BioDiesel-10™ is used in one vehicle, the system producing SeaForest BioDiesel-10™ removes from the atmosphere all the carbon input from its production plus the carbon input of that vehicle, and the equivalent of nine others of the same fuel usage. Use by the world transportation industry of SeaForest BioDiesel-10™ for 10% of its needs would remove the transportation industry from atmospheric carbon equations. And the introduction of Diesel Hybrids will cut the fuel use, whatever its source, in half.

The development of SeaForest BioFuel™ farms will not represent a cost to society but rather an opportunity to worldwide investors looking for attractive economic returns. These farms will also yield significant environmental and social benefits for host countries and the entire planet.

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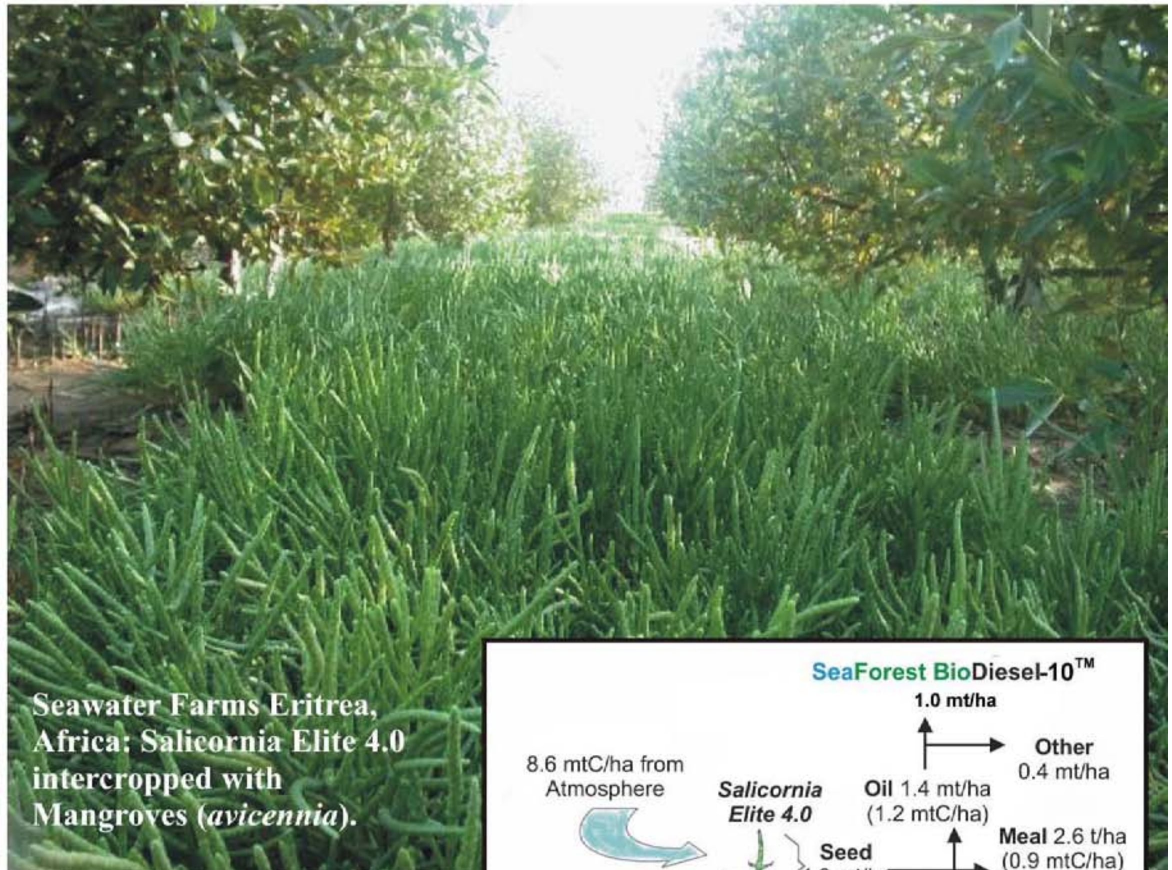
Figure 13. Calculations for SeaForest BioDiesel-10™.

System Atmospheric Carbon Benefit (SACB) for SeaForest BioDiesel-10™

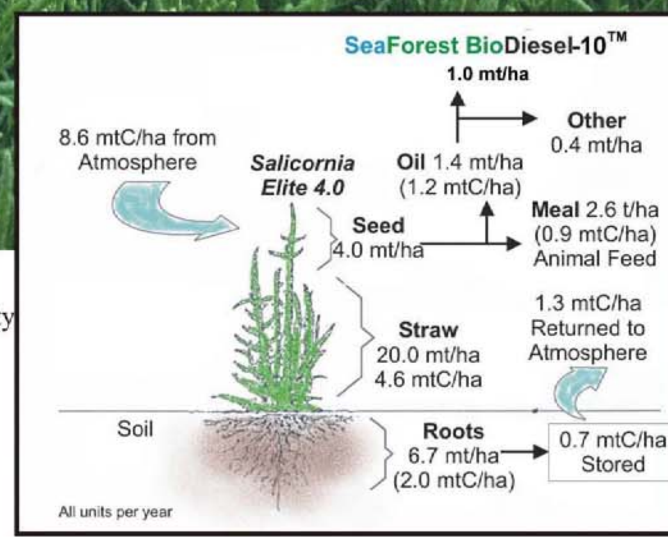
Oak Ridge National Laboratories was contracted to validate the carbon storage (sequestration) mangrove forest at Seawater Farms Eritrea. The data was part for UN / World Bank Certification

Mangrove Trees Yield:

- 35.0 metric tons of roots per hectare per year
- 18.0 metric tons of leaves per hectare per year
- 10.6 metric tons of stems per hectare per year



Salicornia Elite carbon analysis is from University of Arizona and Electric Power Research Institute project with adjustments for increase yield and growing season.



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Sea Level Rise

The oceans are rising now at a rate of 2.6 centimeters per decade. There is considerable difference in expectations regarding how levels will increase. The Potsdam Institute, "A Semi-Empirical Approach to Projecting Future Sea-Level Rise," predicts a SLR of 0.5 to 1.4 meters by 2100. Prudent planning calls for our preparing for a one-meter rise this century, i.e. 10.0 centimeters rise per decade while we solve global warming. Such a high SLR would come later in the century. The building of seawater farms can be accelerated, when necessary, to match an increase that large. However, if the rate of SLR stays the same, and 25 million hectares of seawater farms are designed and built in one decade (the same rate we built freshwater-irrigated agriculture from 1950 to 2003), SLR can be stopped in that time with a level less than 3.0 centimeters above today's. If there is public alarm and awareness regarding damage from an increasing SLR rate, seawater-irrigated farms could be built faster, and still prevent sea level from being higher than a few centimeters above the present level. And, in fact, in the future it can be lowered.

Keeping SLR this low will save the Florida Everglades and other treasures, and avoid worldwide projected protection and damage costs of hundreds of billions of dollars from higher sea level.

World investment for the 25 million hectares of seawater farms will be between US$50 and US$100 billion dollars (depending on host country sweat equity) at $2,000 per hectare, or perhaps twice that depending on numerous international and local factors including pace of development. Even at US$100 billion dollars the capital investment is far less than sea level rise cost avoided. And, economic returns, even at the upper investment level of $100 billion, support the creation of new environmentally enhancing businesses.

Of the 191 countries of the world, 156 have coastlines. All 156 have an interest in stopping sea level rise.

The formal paper, from which this is selected, will specify 34 of the 156 countries as likely candidates for the first Integrated Seawater Agriculture and communities. Worldwide, there already exists much of the installed seawater aquaculture pumping capacity to remove seawater from the oceans at a rate to stop SLR. Designing to use existing capacity as is being done in Mexico is a significant opportunity.

The Hermosillo coastal plain in Sonora, Mexico, is where Seawater Farms Bahia Kino is being developed.

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There, along less than 100 kilometers of coastline, existing shrimp farms are being expanded to have an installed pumping capacity of 1,500 cubic meters per second of seawater. That is 30% of the 5,000 cubic meters per second flow rate of the ice melt from Antarctica. Figure 14 (page 19) shows utilization of a 1,000-cubic-meters-per-second seawater river.

Opportunities for "seawater-based businesses" associated with stopping SLR are numerous. There are good economic returns from the sale of quality seawater farm products. Additionally, there will be income from the associated "products" of new freshwater resources, atmospheric carbon removal payments (SFBK is a project of the World Bank's BioCarbon Fund), and possible future income from contributions to increases in biodiversity (a discussion paper by Shell International Ltd. and The World Conservation Union, "Building Biodiversity Business," suggests that opportunity in the future.)

Further, it is likely that the transportation industry's transition out of the global warming problem will be led by regional and local consortia, consumers, and innovative automotive marketing groups which respond to the world's needs in this area with unique producer-seller-buyer partnerships. Seawater farm developers can be part of and benefit from such partnerships. Vehicles of the future and their SeaForest BioFuels™ that stop SLR will merit premium prices.

Further expansion of Integrated Seawater Agriculture by a factor of ten (to 250 million hectares) is needed and conceivable from the standpoint of available land (desert coastlines) without competition with food production resources. Nor does an Integrated Seawater Farm compete for fresh water.

Two hundred and fifty million hectares of Integrated Seawater Farms (less than current world irrigated agriculture) will remove carbon dioxide from the atmosphere at a rate such that, when combined with energy use efficiency improvements and large-scale use of biofuels, global warming itself can be corrected. We must do that.

Carl N. Hodges
Chairman
The Seawater Foundation

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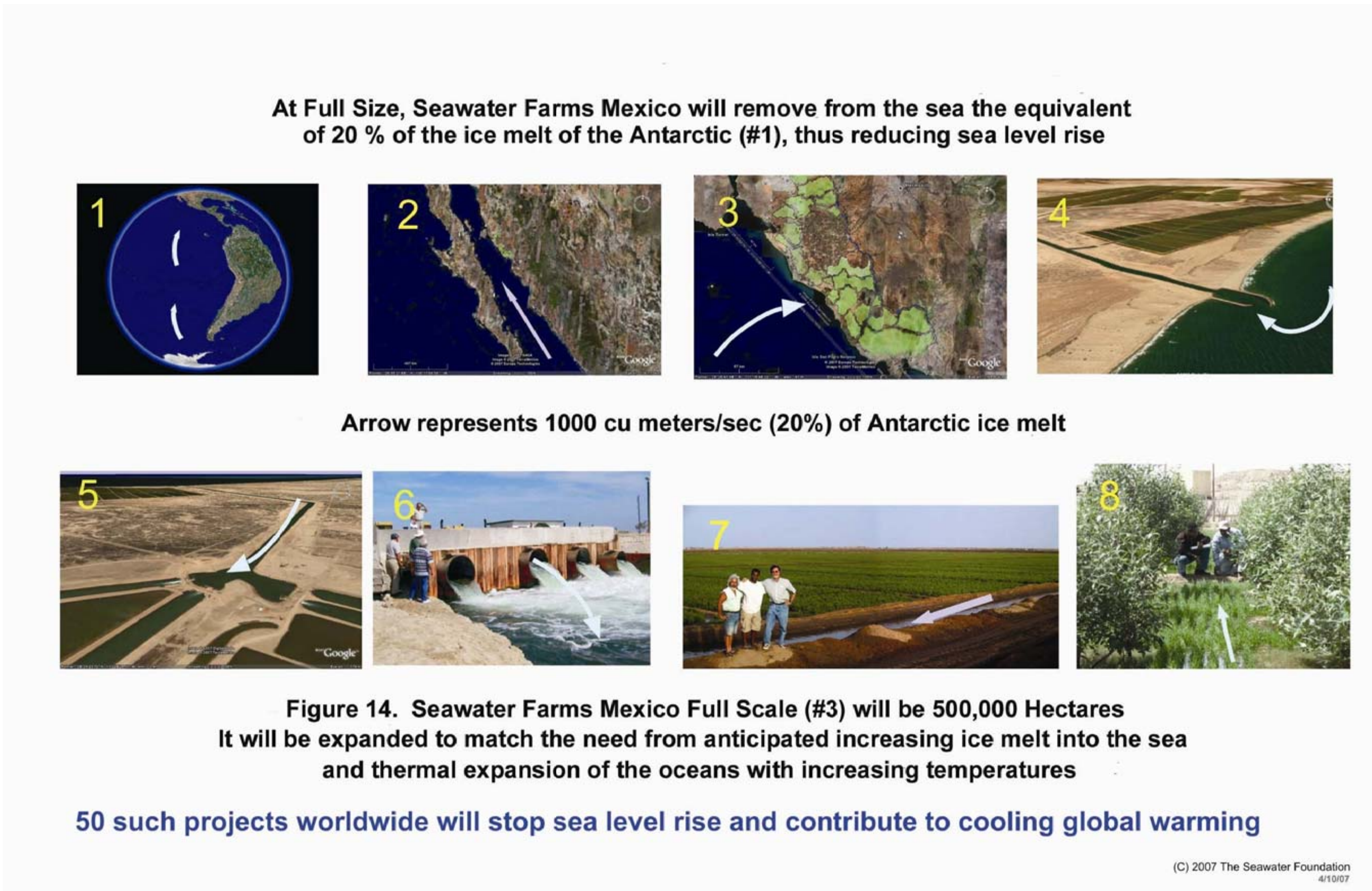

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2. Roberts, Dr. Walter Orr and Henry Lansford, *The Climate Mandate*, W. H. Freeman & Co., July 1979, pp. 197.

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Links

1. *Greening of Eritrea* DVD; Hodges, Carl N., "Lessons from Africa...About the World", English draft of article which appeared in Tokyo Electric Power Company's magazine, *ILLUME*, June 2004.

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