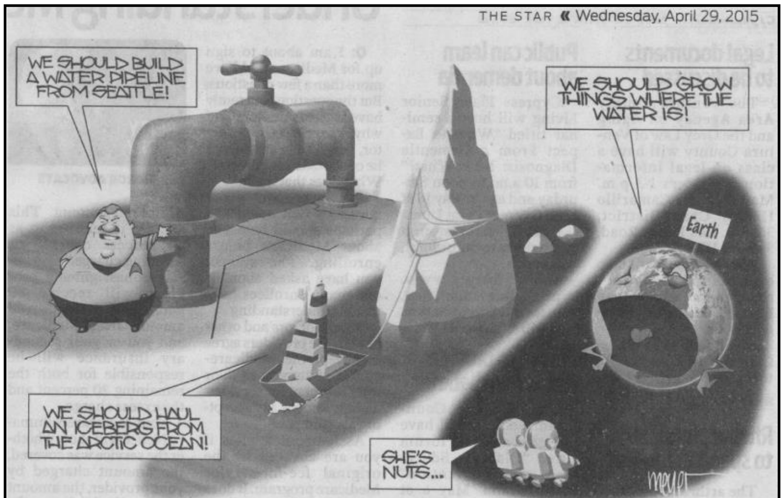
International Integrated Water Project©
Increasing agriculture within the safe yield of the Colorado River
Hasan Consultants and Ocean Foresters

Synopsis

Most of Earth's water is in the oceans, salty, but not too salty for growing food. California's Salton Sea is too salty, but could become a model of California salt-water agriculture.

Before that, the Salton Sea can be an instant fresh water resource extending from San Diego to Tucson and San Francisco to Mexicali.



The water is in California's revived Salton Sea!

Nutshell – Pump a million acre-feet per year (MAF/y) of Salton Basin groundwater into Salton Sea. Pump only the "worthless" groundwater that cannot be used for terrestrial agriculture because it is nearly one third as salty as sea water. The lousy groundwater keeps the Sea full. With the Sea full, the Imperial Irrigation District is free to conserve nearly 2 MAF/y.

Within a few years start desalting a half MAF/y of saltiest Sea water, after a few years, Salton Sea salinity will be less than the Sea of Cortez. We then nearly double the agricultural output of Salton Basin while also improving biodiversity in the Sea. The geothermal energy at the south end of the Salton Sea makes desalting there less expensive more environment-friendly than desalting on California's Pacific coast. Also, the combination of desalting and water conservation allows spreading the cost of desalting half a MAF/y over the entire 2.5 MAF/y made availablefor water trades.

It will rain eventually. Start building groundwater recharge facilities to capture Colorado River floods.

Innovation Integration – Hasan Consultants and Ocean Foresters propose an innovation study to drought-proof Colorado River water users and increase business opportunities in the Coachella Valley and Mexico's hydrologic regions I. Baja California Peninsula and II. Northwest.

The International Integrated Water Project (IIWP) can be an infrastructure investment which rebalances Colorado River safe yield with Colorado River allocation even while it resolves the Quantification Settlement Agreement and while increases water supply and efficiency for the population of the area shown in Figure 1. These joint benefits become possible because the IIWP allows the people of the Coachella Valley and Mexicali to leverage their resources for a net increase in economic productivity.

The IIWP will involve:

- Pumping local brackish groundwater into the Salton Sea. This is salt balance pumping of 0.3 to 1 MAF/y of groundwater.
- Operating the International Energy+Water+Food Technology Development Campus at the south end of the Salton Sea using stranded geothermal energy resources and revived aquaculture.
- Desalting 0.3 to 0.8 MAF/y of the saltiest Salton Sea water using Campus-developed technology.
- Trading the desalted water and conserved Colorado River water generated by sustainably reviving the Salton Sea generally within the benefiting area, Figure 1.
- Eventually, exporting a few MAF/y of desalted Sea of Cortez to San Diego, Los Angeles, Las Vegas, and Tucson or exporting the Campus-developed solid salt, no-brine, desalting technology to the coasts.

Figure 1 – Area benefited by IIWP

Potential regional/international benefits and issues include:

- Water storage – a) The use of about 4,000 MAF of groundwater storage[1] is currently limited by the water available to recharge groundwater; b) Allowing annual variations in the salt removed from the Salton Sea has a safe yield near 2 MAFY, even while holding area-average salinity constant.
- Renewable Energy – Geothermal electricity capacity on the order of a few thousand MW (worth nearly $1 billion/yr) is available at the south end of the Salton Sea.

[1] Lawrence Livermore National Laboratory, January 2008, "Groundwater Availability within the Salton Sea Basin"

- Construction – Construction of the water conveyance, desalting, energy, and aquaculture facilities may add about $3 billion/yr for ten to twenty years into the international area.
- Business – The combination of relatively inexpensive renewable energy and pure water will make the area around the Salton Sea attractive for high-tech industries, potentially adding another $1 billion/yr.
- Agriculture – During a mega-drought agriculture production will drop. Every 1 MAF of new fresh water or equivalent in water use efficiency can maintain $400 million/yr of agriculture through droughts.
- Colorado River Delta/Estuary – Annual pulses of fresh water on the order of 0.03 MAF may be worth a few $100 million/yr restoring Delta fisheries, Sea of Cortez fisheries, eco-tourism, migrating bird habitat, and biodiversity.

We have commenced discussions with Mexico through Oxnard Consul Berenice Diaz Ceballos and engineers with Comisión Nacional del Aqua. We are also discussing the IIWP with the Colorado River Task Force, the Salton Sea Authority, and others. Our innovation study would better quantify, document, and suggest allocation of the benefits and costs of the IIWP. We can complete our portion of the Innovation Study within 6 months of award. Our recommended budget is $200,000.

Our team includes:

Mohammed A. Hasan, PE, FASCE, 805-218-5574, mhasan@hasanconsultants.com. 40 years of experience with water resources including planning, design, and construction.

Mark E. Capron, PE, 805-760-1967, markcapron@oceanforesters.org. 35 years of experience with U.S. Navy ocean facilities and water resources, currently organizing the Ocean Foresters. Both Hasan Consultants and Ocean Foresters are located at 2436 E. Thompson Blvd., Ventura, California, 93003.

ATSI (provides the engineering and fabrication for WaterFX who has piloted an absorption solar thermal desalting technology costing less than $0.41/m^3$ and rock salt by-product, not brine)

Pacific Northwest National Laboratory and Genifuel (hydrothermal liquefaction biomass-to-energy as part of the nutrient and minerals recovery process)

PRD Tech, Inc. (commercial grade liquid ammonia fertilizer recovered from the clear water produced by hydrothermal liquefaction or wastewater treatment)

Initial Phasing and Financing

Phase 1a – Water+Energy+Food Technology Campus

The Water+Energy+Food Technology Campus would host technology developers who would sell their product while demonstrating their process at commercial scale. The Campus would provide the environmental documentation and connections to geothermal heat, electricity, salt water, etc. The Campus would buy and transport produced product and accept byproducts at an agreed rate. Potential products from selected technologies:

a. Several water technology developers might demonstrate with the Campus buying 500,000 AF over ten years for less than $500/AF. The by-product of this technology will be solid salt, not liquid brine. The water developers would lease space for solar energy or purchase geothermal heat or purchase electricity from the Campus.

b. Several groundwater storage and recovery technology developers would participate in the Campus from locations around or under the Sea. They would sell poor quality water to the Campus for the purpose of keeping the Sea full while creating space for groundwater recharge. Up to about 200,000 AFY, this poor quality groundwater could substitute for the direct use of Colorado River water which is slowing the rate of Sea drying. The hydraulic fracturing technology developed for oil and gas extraction is directly applicable to both geothermal energy and groundwater recharge and recovery.

c. Several salt mining and salt stabilizing technology developers might coordinate with the Campus to extract products and stabilize the salt produced by the water technology developers.

d. Several geothermal energy developers might demonstrate well drilling and heat energy production with the Campus buying the produced heat energy and selling the heat to the water technology developers.

e. Several thermal-to-electricity developers might demonstrate solar thermal and geothermal electricity production with the Campus buying the electricity. The thermal electricity developers could purchase single pass cooling water from the Campus. That warmed water might be sold to the water technology developers.

f. Several marine agronomy developers might provide nutrient remediation of the Salton Sea while the Campus buys their biomass products until the Sea is rejuvenated.

g. A dozen biomass-to-energy developers might transform biomass from the Sea, local agriculture, wastewater treatment plants, and municipal solid wastes to energy. The Campus might have several sites to include existing wastewater treatment plants or landfills.

Campus construction and operation might be financed over the long term by:

a. The California Department of Natural Resources.
b. Many water agencies through the Water Environment Research Foundation and the Water Research Foundation.
c. The U.S. Department of Energy.
d. The U.S. Department of Agriculture.
e. The U.S. Bureau of Reclamation.
f. Mexico's Comisión Nacional del Aqua.

It is our understanding the California Department of Natural Resources will request competitive proposals for funding via California's Water Bond 2014. We would like to assist others in submitting proposals for seed funding of the Water-Energy-Food Technology Campus. We should discuss the proposal process and the appropriate categories which might include:

- A portion of the $475 million "… to support projects that fulfill the obligations of the State of California."
- A portion of the $810 million "… projects included in and implemented in an adopted integrated regional water management plan consistent with Part 2.2 (commencing with Section 10530) of Division 6 and respond to climate change and contribute to regional water security…" Must the plan have been adopted before the Water Bond became law?
- A portion of the $2.7 billion "… associated with water storage projects …"
- A portion of the $725 million "… for water recycling and advanced treatment technology projects."

For example, both Salton Sea and Westlands have the same long-term need to remove salt from soil and prevent toxic dust storms. The Water+Energy+Food Technology Campus can be a forum for more rapidly improving the economics and sustainability of pure water and solid salt production, storage, and reuse than can be achieved by Westlands operating alone.

Phase 1b – Starting aquifer storage and recovery

Per the 2008 Lawrence Livermore National Laboratory study, "As a whole, groundwater storage in the basin is very large, potentially as high as 4.5 to 6.5 billion acre-feet in current estimates, yet much of this confined to greater depths where quality is poor (high salinity), producibility is low (poor permeability and accessibility) and natural recharge, required for sustained use as a supply, is not well demonstrated from available data."

Other possible storage options in California have the same issue. When the storage is too big, there will not be enough water to fill it. The IIWP has two water sources for supply and groundwater recharge: the Colorado River, and the Ocean (actually the saltiest water in the Salton Sea). As an initial Climate Change adaptation, the IIWP members might target 60 MAF of groundwater storage. That would yield 2 MAFY for a 30-year drought. Ideally, the system could recharge several MAF during each wet year. The geothermal desalting operation might operate at a steady 1 MAFY. During wet to normal years it enables 1 MAFY of recharge. During dry years, 2 MAFY supply is half from desalting and half from stored groundwater.

Phase 2 – Salton Sea Restoration and Water Storage/Conservation

Little of California's allocation of Colorado River water can be conserved unless the Salton Sea is kept full and its salinity managed. This because the Salton Sea can only be fully restored and sustained with water input equal to evaporation and salt removal initially in excess of salt input. Table 1 shows how to decrease salinity and maintain level with either local brackish groundwater or water from the Gulf of California (aka Sea of Cortez).

Table 1 – Annual mass balance of Salton Sea level and salinity for four situations

Parameter - **Year 1**	units	Max conserving with groundwater	Max desalting with groundwater	Max conserving with Sea of Cortez	Max desalting with Sea of Cortez
Start of year average Salton Sea salinity	mg/L TDS	50,000	50,000	50,000	50,000
Volume of Salton Sea, beginning of year	MAF	7.6	7.6	7.6	7.6
Total mass of dry salt in Salton Sea	M tons	473	473	473	473
Annual evaporation from Salton Sea	MAF	1.4	1.4	1.4	1.4
Average salinity of used Colorado River water drainage into Salton Sea	mg/L TDS	2,400	2,400	2,400	2,400
Fresh water allocations from Colorado River for agriculture and other human uses within the Salton Sea watershed	**MAF**	**1.8**	**3.6**	**1.8**	**3.6**
Desalted Salton Sea water used locally (mixed with Colorado River water)	**MAF**	**0.3**	**0.6**	**0.8**	**0.8**
Fraction of desalted and Colorado River water draining back to the Salton Sea	%	15%	25%	15%	25%
Fresh water drainage volume	MAF	0.3	1.1	0.4	1.1
Dry mass of salt in fresh water drainage	M tons	0.9	3.1	1.2	3.3
Groundwater pumped directly into the Salton Sea	**MAF**	**1.0**	**0.3**		
Gulf of California water imported direct to the Salton Sea	**MAF**			**1.0**	**0.3**
Salinity of brackish groundwater or Gulf of California salt water imported directly into the Salton Sea	mg/L TDS	10,000	10,000	35,000	35,000
Dry mass of salt in imported water	M tonnes	13	4	42	11
Salt removed as rock salt when desalting Salton Sea water of average salinity	M tonnes	19	37	50	50
Volume of Salton Sea, end of year	MAF	7.6	7.6	7.6	7.6
End of year average Sea salinity	mg/L TDS	**49,501**	**46,792**	**49,327**	**46,282**

All four situations maintain Sea level with the same 7.6 million acre-feet (MAF, 1 MAF = 1.2 billion cubic meters) at the beginning and the end of the year. All four situations reduce the Sea's average salinity. The two maximum desalting situations would reduce salinity below the 35,000 mg/L of Gulf water at the end of the fifth year.

Avoiding transmission costs on the locally produced geothermal electricity can make pumping groundwater 25% less expensive, than for other locations. A small portion of the year-round cool groundwater in single-pass heat exchangers can decrease electricity costs 10 to 20%. The pumped groundwater is too brackish[2] for agriculture, it must be pumped to create space to store higher quality water, this arrangement is known as salt balance pumping.

Table 2 – Financing Phase 2 restoration with water conservation

Parameter	units	Max conserving with groundwater	Max desalting with groundwater	Max conserving with Sea of Cortez	Max desalting with Sea of Cortez
Fresh water allocations from Colorado River for agriculture and other human uses within the Salton Sea watershed	MAF	1.8	3.6	1.8	3.6
Desalted Salton Sea water used locally (mixed with Colorado River water)	MAF	0.3	0.6	0.8	0.8
Groundwater pumped directly into the Salton Sea	MAF	1.0	0.3		
Gulf of California water imported direct to the Salton Sea	MAF			1.0	0.3
Conserved water volume	**MAF**	**1.8**	**0.0**	**1.8**	**0.0**
Full cost of pumping groundwater or importing Gulf water, desalting Sea water, distributing desalted water, and storing solid salt	$/AF	$1,000	$1,000	$1,000	$1,000
Water trade cost rate (purchase of conserved water by non-IID members)	$/AF	$300	$300	$300	$300
IID's annual desalting cost ("-" indicates a net income to IID members)	**$M/yr**	**-$240**	**$600**	**$260**	**$800**
Annual cost of non-IID members	**$M/yr**	**$540**	**$0**	**$540**	**$0**

[2] The LLNL report does not address water quality. Appendix B of the IID Desalination/Groundwater Development Feasibility Study, October 2012, by GEI Consultants, covers only the area under the Imperial Irrigation District. It suggests substantial water less than 10,000 mg/L TDS is available.

The groundwater system will not be single in-out wells. Multiple wells and percolation ponds will act together. Withdrawal wells would operate between 0.3 to 1 MAF as needed to maintain Salton Sea level. Recharge facilities will vary their recharge between 0.2 MAF to 2 MAF.
The Phase 2 restoration and water conservation might be financed by water trades among members of the Colorado River Water Users Association or as part of the Secretary of Interior's adjusting allocations to better fit the safe yield of the Colorado River System. Table 2 shows possible arrangements for water trades in each of the four Situations of Table 1. The four situations of Tables 1 and 2 bracket a more likely arrangement wherein the participating agencies treat the IIWP as if it were a water storage or a water supply insurance project. That is a semi-fixed budget adjusted each decade to fit current understandings of the Colorado River system's safe yield.

The five years of maximum desalting, need not be consecutive, but returning Salton Sea salinity and chemistry near that of Gulf water is essential to realizing the aquaculture income mentioned in Table 3. The maximum conservation situations would be employed during droughts and may be employed indefinitely as an infinite reservoir with a sustainable safe yield of 1.8 MAF per year, relative to 2014 Colorado River water allocations.

Technology and Cost Issues related to Phase 2:

1) Desalting at the Sea takes advantage of the Salton Sea's geothermal resources.
2) Desalting at the Sea allows for importing more Gulf water than is desalted.
3) The full desalting cost in Table 2 of $1,000/AF is conservative in that it does not include: a) WaterFX has indicated the $450/AF they predict for their solar thermal desalting would be less expensive with geothermal heat; b) Table 2 contains few of the potential incomes made possible when cool groundwater or cool Gulf of California is imported.
4) Because Gulf water is more corrosive before desalting, Hasan Consultant's innovation study includes seawater conveyance without metal in contact with the water or excavation deeper than about 60 feet.

Table 3 is a more optimistic estimate of the net cost of new water on a per acre-foot basis which may be viewed as the lowest likely cost of new water.

It is our understanding the California Department of Natural Resources will request competitive proposals for funding via California's Water Bond 2014. We would like to assist others in submitting proposals for Phase 2: Salton Sea Restoration and Water Storage/Conservation. We should discuss the proposal process and the appropriate categories which might include:

- A portion of the $475 million "… to support projects that fulfill the obligations of the State of California."
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Table 3 – Expenses and Revenues for Salton Sea Restoration and Water Storage/Conservation

Expenses ($/AF)		
	Groundwater use and recharge system capital and operating expense for Phase 2 (A groundwater project is quicker, but the gravity flow drop into the Salton Sea makes Sea of Cortez water costs closer to $200 per AF.)	$300
	Desalting, salt reuse, local product water distribution after a few years of Phase 1 – Campus operation	$700
	Total expenses	**$1,000**
Revenue ($/AF)		
	Payments from electricity producers using the cooler single-pass condensing water	$200
	Lease fees from the Marine Agronomy operations	$100
	Windfall tax on improved property values and recreation	$30
	Payments from water trades	$300
	California & Federal funding for hazard prevention and environment restoration	$100
	Total revenue	**$730**
Total of revenue minus expenses		**$270**

Phase 3 – Moving pure water or distributed desalting

The technologies discovered and refined during a decade or two of operating the Phase 1 International Energy+Water+Food Campus will be constantly evaluated in light of the local and global situation for water, energy, and food. The technologies will make two options increasingly viable:

A) San Diego, Los Angeles, Las Vegas, Phoenix, and Tucson arrange to have pure water delivered directly to the Colorado River Aqueduct and the Central Arizona Project at Lake Havasu or the high point of the Colorado River Aqueduct near the Salton Sea. The combined capacity of the Colorado River Aqueduct and the Central Arizona Project is 2.8 MAF/yr.

   The desalting for export may occur in Mexico with its abundant solar thermal energy, tidal energy in the Sea of Cortez, existing salt flat storage space (Laguna Salada), and need for solid salt to build barriers to the rising Sea of Cortez. Desalting for export might also occur at the south end of the Salton Sea with its geothermal heat resource.

B) San Diego, Los Angeles, and Mexicali desalt ocean water locally while Phoenix and Tucson desalt used Colorado River water.

In either case, the Phase 3 desalting and transportation might be financed by water trades among members of the Colorado River Water Users Association or as part of the Secretary of Interior's adjusting allocations to better fit the safe yield of the Colorado River System.

In addition to the area of Figure 1, the technologies of the International Campus can be employed at cities such as La Paz, Valparaiso, Abu Dhabi, Melbourne, Alicante, Nouakchott, and others.