West Hawai`i Offshore Electromagnetic Imaging Survey

(updated 09/29/2023)

Summary

Using non-invasive, non-destructive and transient geophysical imaging techniques, this study will generate a map of the electrical resistivity of rock formations beneath the seafloor in West-Hawai'i.

Purpose

To identify and map reservoirs of submarine freshwater offshore of Hualalai volcano on the Island of Hawai`i.

Rationale

Seawater-saturated basalts have well defined electromagnetic resistivity. In contrast to this background signal, sub-marine rock formations permeated with freshwater yield anomalously high resistivity measurements which can be used to map the location of pockets of freshwater 100's and 1'000's of feet below the seafloor.

Background

In 2018, using marine controlled source electromagnetic (CSEM) methods, a team of researchers from the University of Hawaii and Scripps Institution of Oceanography identified what is theorized to be a deep confined layer of fresh or brackish water where, under standard hydrological models of ocean islands, there should be none.

The team proposes (Attias et al., 2020[i]) this "deep water" is an extension of the island's onshore aquifer, with rainfall being captured on the exposed slopes of the island's volcanoes and channeled beneath the conventional basal freshwater lens through a multilayer formation of water-saturated basalt interbedded with low-permeability layers of ash and soil.

This discovery, along with other evidence of submarine vents discharging freshwater to the ocean on a regional scale, may help explain significant discrepancies between groundwater recharge of the aquifer and discharge from that body of water at the coastline. The conventional hydrologic models come up short – there is a large amount of "missing water".

The 2018 survey was limited in scale but provided strong evidence of what may be a large reservoir of freshwater in West-Hawai'i, extending from far inland to miles offshore. The present study aims to confirm, extend and add detail to that earlier effort.

Significance

If one or more pockets of "deep water" are identified and confirmed, scientific information gathered on the capacities and dynamics of those reservoirs will inform water resource modelling and management decisions for the region and may highlight them as a significant source of freshwater to support Hawai`i Island's human population.

Methods and Technology

The proposed survey work is divided into two distinct groups of activities: the larger portion entails use of "CSEM" in water depths of 60 to 75 meters. A second portion allows for collecting data using passive magnetotelluric methods further offshore and at greater depths than the CSEM survey.

CSEM techniques have been used worldwide since the 1990's – principally for offshore oil and gas exploration. The study-team has developed improvements to the technology that yield higher resolution measurements using significantly lower signal strengths than are conventionally applied. Nonetheless, CSEM surveys share a common methodology (Figure 1): a signal generator broadcasts an electromagnetic signal, much as cellular tower does - but at very much lower signal strengths and frequencies. As this signal travels through matter (air, water, rock) it is attenuated (loses power) and is reflected according to the composition of that matter. CSEM receivers, much like a cellphone, listen for the reflected signals and measure the degree of signal attenuation. Post-processing of those return signal data streams highlights differences in the degree of attenuation, revealing variation in the electrical resistance of the medium through which the signal has passed. By layering many such data streams in time and space, 2-dimensional and 3-dimensional maps of those variations can be assembled, thereby revealing hidden structure.

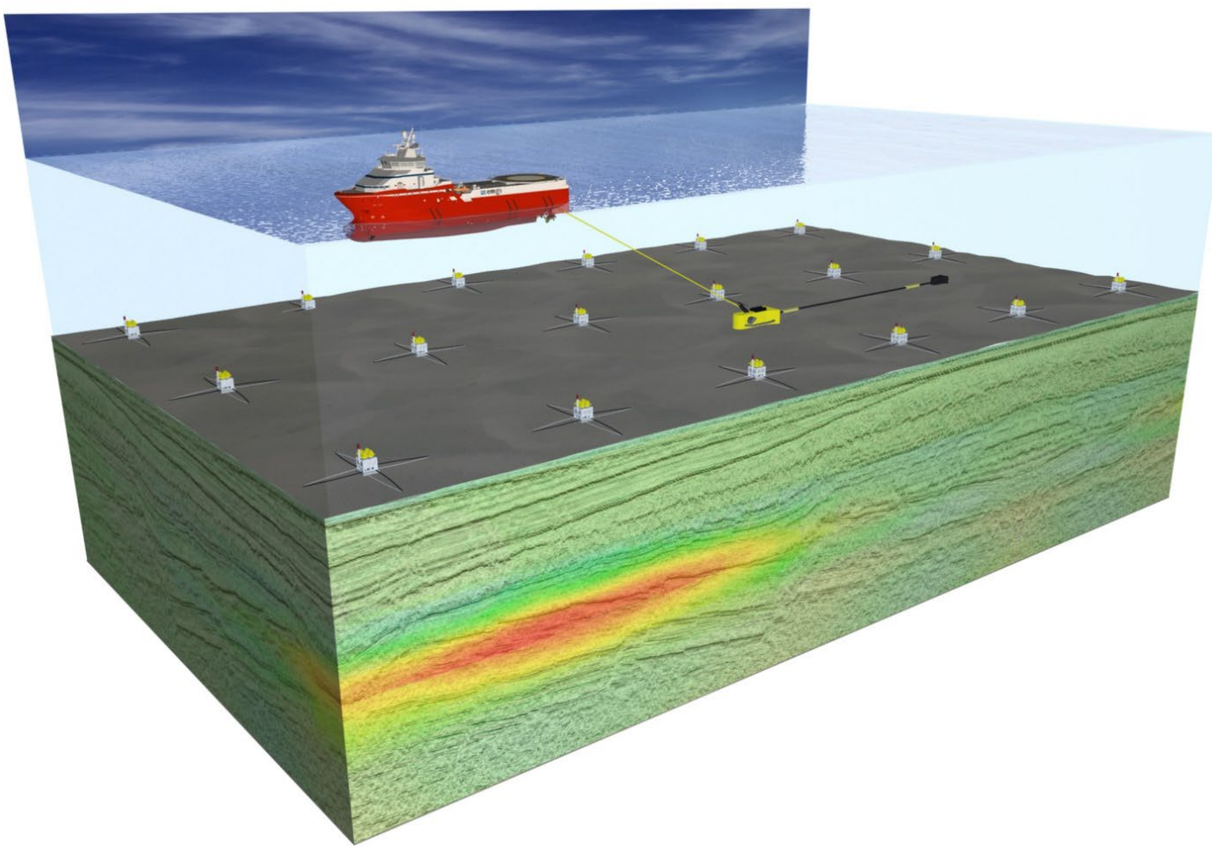

Figure 1 Schematic of CSEM near-bottom survey (Source EMGS 2021[ii])

For the CSEM portion of this study, we propose to deploy sets of eight passive instrument packages (the "receivers") on the seafloor at a time, setting these in straight rows at selected locations and water depths, and then to tow a 1,000 meter-long umbilical just below the water's surface at a speed of 3 knots directly above, and/or in proximity to the rows of sensors. The umbilical is comprised of additional receiver instruments as well as the source signal generator itself, all connected to the towing vessel by a spooled cable. The generator issues an electromagnetic square-wave signal oscillating at approximately 1 Hertz (1 cycle per second), with a power at source of 100 Amps. By comparison, oil and gas exploration routinely use source strengths of 1,000 and 10,000 Amps.

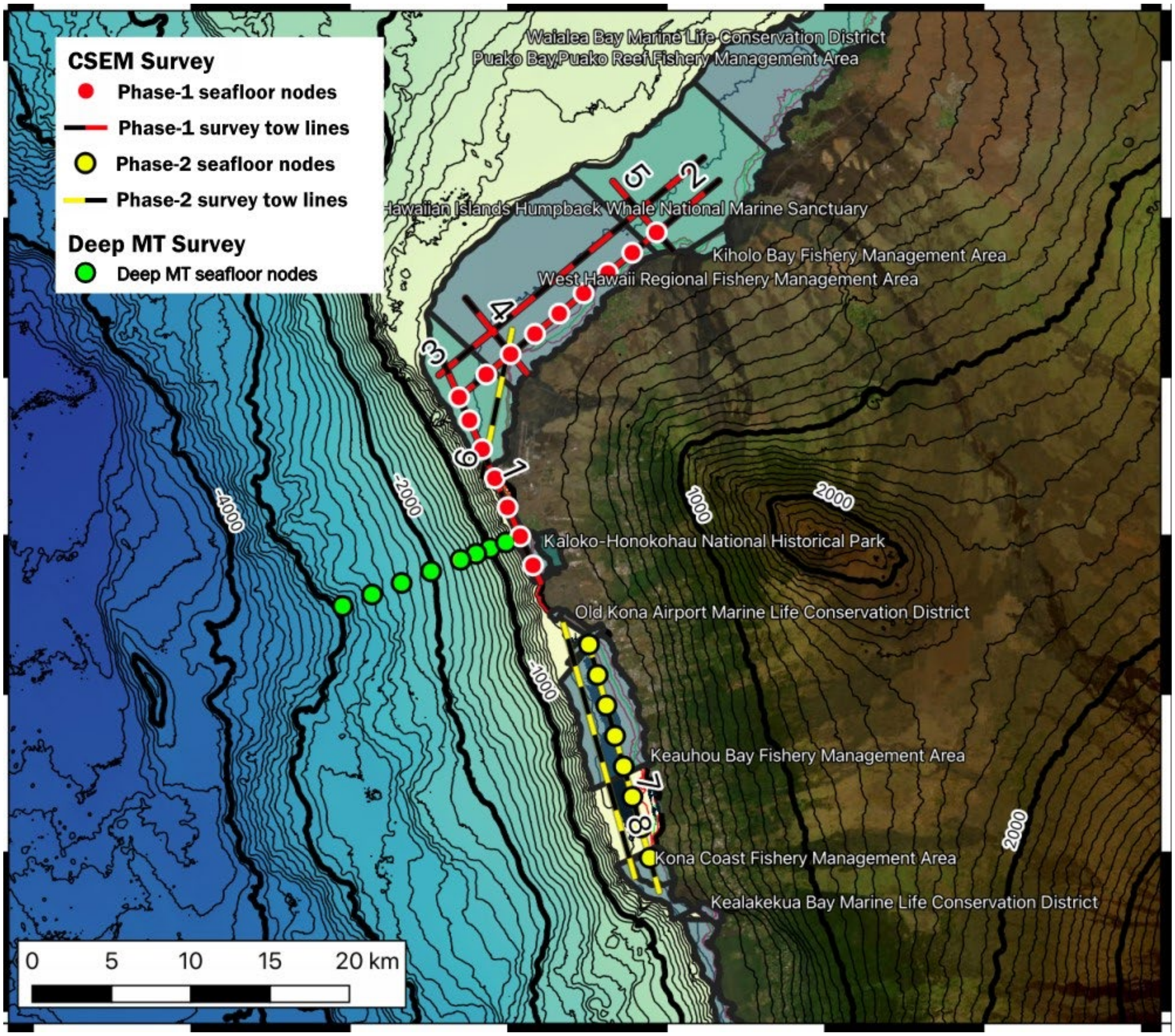

Figure 2 - Proposed CSEM survey area, receiver placements and umbilical tow corridors.

The "Deep-MT" portion of the work plans to collect data further from shore – hence deeper than is amenable using the CSEM method described above. Eight of the same receivers will be deployed – but configured for magnetotelluric mode, in which the array measures the natural geomagnetic fields from the rocks below without the superimposed electromagnetic forcing signal used by CSEM. Thus, no umbilical tow is required for this phase of the study.

Study Area and Sequence of Events:

The proposed survey would take place in three separate survey phases: in the first "north" phase between Hou Point (the northern edge of Kiholo Bay) and Honōkohau Harbor (shown in red in Fig. 2), two sets of eight receivers would be deployed on the seafloor at a water-depths of approximately 70 to 75 meters, at specified locations (or "nodes" – shown as circular symbols in Fig. 2), spaced approximately 2,000 meters apart in two straight lines (numbered 1 and 2 in Fig. 2) offshore of the base of the reef escarpment. Once the receivers have been set in place, the survey vessel would then deploy and tow the umbilical in a single pass directly above the two rows of sensors. The survey would then proceed with a similar tow, parallel to Line 2 but offset seaward by 1.2 miles (line 5). Further passes with the umbilical would then take place, starting near to shore and ending 4 miles straight offshore (lines 3 and 4). A final pass parallel to the shoreline facing the Kona International Airport would intersect both lines of receivers diagonally (line 6). At the end of this sequence, all 16 seafloor instrument packages, including their concrete ballast, would be recovered for redeployment in the second and third phases of the survey, each being raised with a lifting line that is released from the package by an acoustic transponder (Fig. 3).

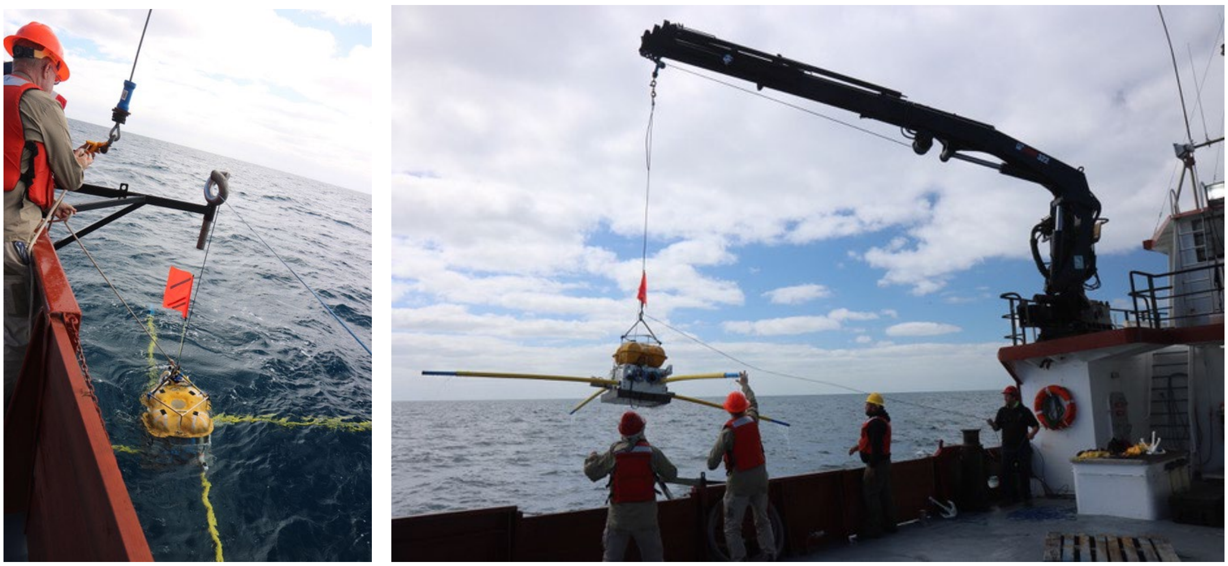

Figure 3 Recovery of CSEM sea-floor instrument package (Source: Scripps Institution of Oceanography)

In its second phase, the survey would focus on the area South of Kaiwi Point (shown in yellow In Fig. 2), using a single row of eight receivers (line 7) approximately parallel to the shoreline between Oneo (Kailua) Bay and Keawekāheka Point at Kealakekua, with the receiver nodes being offshore of the base of the reef escarpment at between 60 and 70 meters water depth - except for one directly offshore of the “Royal Kona Resort” that would be at 48 meters depth. As before, this line would be retraced on the surface with the ship-towed umbilical, followed by a second pass offset from the first by about ¾ of a mile further offshore (line 8).

The final row of eight receivers would be placed in a “Deep MT line” (shown in green In Fig. 2) running offshore from Wāwahiwaʻa Point (at Kohanaiki), starting ¾ of a mile offshore at a water depth of 560 meters and extending offshore 6-½ miles to a water depth of 2,900 meters. The Deep-MT receivers will sit passively on the seafloor and log data for 4 to 5 days while the second phase umbilical tows are taking place.

Upon completion of the second and third phases of the survey, the seafloor instrument packages would once again be recovered by triggering acoustic transponder releases. In the case of the “Deep MT” devices however, because of the water depths at which the instruments will have been placed, rather than recovering the entire package including the ballast using a buoyant lifting line, the transponder would instead release the instrument package from its ballast - allowing it to rise by buoyancy to the surface.

Timing and Duration of the Fieldwork

Scheduling the fieldwork in "low season" both for migrating humpback whales as well as stormy weather and ocean swells, the work plan proposes a start date in early- to mid-May 2024. As described above, the overall project scope is divided in to 3 phases - the first (North) phase is planned for up to 8 days: 2 days to deploy the receivers, followed by 2 days for the towing the CSEM umbilical, 2 days allotted for recovery of the receivers and 2 days for contingencies and down-time. The second (South) phase of the CSEM work, having fewer umbilical tows, is then expected to take place over the following 6 days, including 1 day of contingency. The "Deep MT" work would start concurrently with the second phase and would last one to two days beyond it. All told, the total elapsed duration for this fieldwork – from the time the first receiver is deployed to when the last one is retrieved, is two weeks.

Risks, Impacts and Mitigation

Footprint on the seafloor:

The remote listening-device instrument packages used in this type of survey are mounted on square pedestals of concrete 1 meter on a side by 10 centimeters thick. These ballasts sit on the seafloor, and along with four 2-meter-long antenna poles that project outward from the instrument package (Fig. 3), represent the "footprint" of the device on the seafloor. When data collection is complete the instrument packages are recovered using an acoustic transponder to trigger one of two electronic release mechanisms on the package depending on the water depth in which the receiver is deployed: for placements at less than 100 meters, it causes deployment of a lifting line with a float to the surface, allowing the entire package, including the concrete ballast, to be raised to the surface and recovered using a shipboard winch, leaving nothing behind on the seafloor. For the "Deep MT Line" of eight receivers, for which such a solution is technically infeasible due to water depth, the release would detach the instrument package from its concrete ballast, leaving this on the seafloor and allowing the rest of the package to rise by internal buoyancy to the surface, where it would be recovered onboard ship.

In a 2007 USGS study of the benthic habitats and geological resources offshore of Kaloko-Honokohau National Historical Park, Gibbs *et al.* [iii] classify the seafloor at 60+ meters water depth offshore of the Park as the "Deep Slope" habitat zone. Using a combination of data collection methods including LIDAR and georeferenced photography, the study is the most detailed and comprehensive of its kind to focus on benthic structure offshore of West Hawaii and is approximately centered within the study area defined in this current proposal. The Gibbs *et al.* study terminates just below base of the shelf escarpment somewhat inshore of the depth contour this present survey is to focus on, and the report describes the zone as predominantly a gently sloping, uncolonized sand sheet where, in places, coral rubble, scattered rocks, and large angular and rounded boulders are present The habitat was found to be mostly uncolonized; however, small colonies of lobate *Porites lobata* (a stony coral) were observed at low densities on some of the boulders. Sea cucumbers and garden eels were also observed to inhabit this area.

Confirmed by hundreds of hours of accumulated observations using manned submersibles and remotely operated vehicles offshore of Keahole Point (NELHA unpublished), as distance increases from the base of the escarpment, (except for man-made objects) solid surfaces such as rocks and boulders which corals might colonize become rare to non-existent very quickly, and light intensities reaching the seafloor at upper edge of the Deep Slope approach the lower limit required for reef-forming corals. Given that all but one proposed deployment location for instrument packages to be used in this study are below this threshold depth, it is reasonable to conclude the near absence of stony corals and other sessile macrofauna throughout much of the proposed study area. The macroorganisms most likely to be encountered in the study area are transient bottom-dwelling fish, rays and shrimp.

Human Interaction with the CSEM umbilical:

On the days of CSEM data collection, the survey vessel will transit to the starting station for the day-start and spool out a 1,000 meters-long "umbilical" to which are attached various instruments and the electromagnetic signal generator. This umbilical is towed behind the survey vessel at a speed of 2 to 3 knots, flying at the water surface. To keep other vessels and the public at bay from this submerged hazard, one or two chase-boats will patrol the area – warning nearby and approaching vessels. In addition, a public information campaign will include outreach meetings with stakeholders and boaters from the area, notifications to the US Coast Guard, DLNR officials at Honokohau small boat harbor and posting notices on bulletin-boards at the harbor.

Non-Human Interaction with the CSEM umbilical:

By intention, the survey timeframe is outside of the time-window when migratory humpback whales are typically present in West-Hawai'i. However, other species of whales and other protected animals (dolphins, seals, turtles, whale sharks, rays, birds) may be present in the study area. To avoid interaction between protected animals and the CSEM umbilical, observers will be posted on both the survey vessel as well as the chase-boats to watch for presence of animals in or near the survey area. Should any appear and persist in the area, the survey transect will be temporarily halted and the umbilical spooled onto the deck of the survey vessel until such time as the animal has moved out of the zone of possible interaction.

Generic effects of CSEM surveys on animals:

Several environmental assessments of CSEM surveys have been prepared for the offshore oil and gas exploration. Among those, a key document (Buchanan et al. 2011[iv]), prepared for the International Association of Geophysical Contractors is an authoritative review of the effects of CSEM surveys on animals. The scope of this Environmental Impact Assessment (EIA) was worldwide and reviewed over 400 reports and publications, providing data and information on hundreds of species of marine mammals, seabirds, sea turtles, and fishes. The study evaluated generic effects of survey activities with at least some potential to affect marine animals such as electromagnetic emissions (EM), noise, light emissions, and accidental events (e.g., strikes and spills). Of these, only the first is unique to CSEM surveys – the remainder being relatively well understood, and amenable to mitigation using common Best Practices.

Electromagnetic fields generated by CSEM:

With respect to EM fields, the Buchanan et al. EIA looked at animal sensitivities to and known uses of EM fields – specifically addressing geomagnetic orientation and navigation, and electroreception. The authors calculate that for the most sensitive organisms (elasmobranchs) *"the horizontal "zone of influence" of a typical [CSEM] source would be less than 400 m radius. In addition, the time of exposure would be on the order of minutes between a moving source and a stationary or mobile animal"*.

The "typical [CSEM] source" referred to in that EIA has a signal strength of between 1,000 and 10,000 Amps. By comparison, the signal strength to be used by the present study is on the order of 100 Amps – thus according to the physics of EM attenuation, the estimated horizontal "zone of influence" for those sensitive species would be reduced to 40 meters radius or less.

Buchanan et al. conclude that even at the higher signal strengths their study focused on, *"EM sources as presently used have no potential for significant effects on any of the important animal groups such as fish, seabirds, sea turtles, and marine mammals. In addition, any cumulative effects from EM surveys are negligible compared to natural EM anomalies, induced fields from natural water currents, and other anthropogenic EM sources such as those originating from undersea equipment especially underwater powerlines and associated electrodes"*.

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[i] Attias E, Thomas D, Sherman D, Ismail K, Constable S. Marine electrical imaging reveals novel freshwater transport mechanism in Hawai'i. Sci Adv. 2020 Nov 25;6(48)

[ii] EMGS. 2021. EMGS website at http://EMGS.com.

[iii] Gibbs, A.E., Cochran, S.A., Logan, J.B, and Grossman, E.E., 2007, Benthic habitats and offshore geological resources of Kaloko-Honokohau National Historical park, Hawai`i (ver. 1.1, May 2016): U.S. Geological Survey Scientific Investigations Report 2006–5256, 62 p.

[iv] Buchanan, R.A., R. Fechhelm, P. Abgrall, and A.L. Lang. 2011. Environmental Impact Assessment of Electromagnetic Techniques Used for Oil & Gas Exploration & Production. LGL Rep. SA1084. Rep. by LGL Limited, St. John's, NL, for International Association of Geophysical Contractors, Houston, Texas. 132 p. + app.