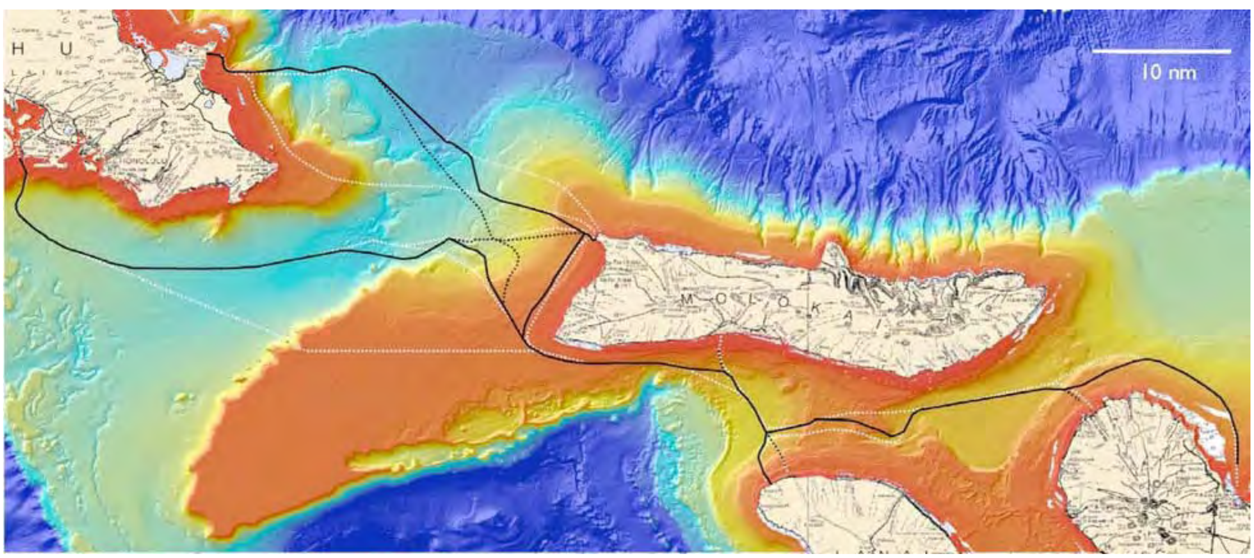
Interisland Cable Ocean Floor Survey Reports



Acknowledgment: This material is based upon work supported by the Department of Energy under Award Number DE-EE0000216.

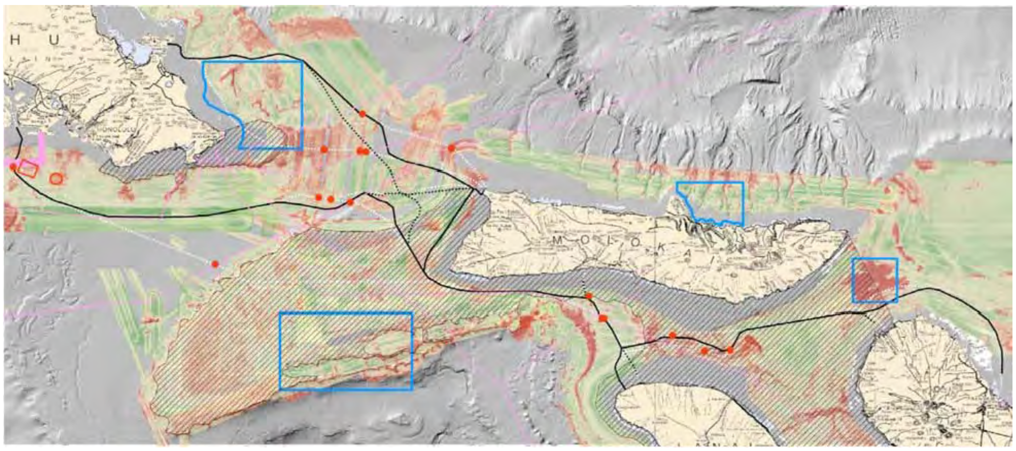
Report 1

November, 2009

Contents

1. Executive Summary

This report contains the results of the ocean floor survey conducted between the Hawaiian Islands of Oʻahu, Lānaʻi, Molokaʻi and Maui. The purpose of this survey was to determine the feasibility of physically laying a power transmission cable on the sea floor between these islands for the purpose of transmitting renewable energy generated on Lānaʻi and Molokaʻi to Oʻahu and possibly Maui. The results of the survey show that laying a power transmission cable between the islands is physically possible via a number of different routes. Each route presents its own engineering and environmental challenges.



Recommended (black) and alternate (dashed) cable routes, other routes surveyed (white dashed), on sunlit bathymetry (gray)and seafloor acoustic imagery (red = strong, green = weak).
Pink = existing cable;
Red dot = observed cable crossing
Blue box = bottom fish refuge;
Red box/circle = dump areas
Ruled area = humpback whale sanctuary

Certain questions, however, remain unanswered, including:

- How to precisely lay the cables around deep-water obstacles, such as former reefs, dumped materials and munitions;
- How to connect the cables to shore under (via micro-tunnels) and/or over (via dredged micro-channels) fringing coral reefs that are up to 2 km across; and,
- Whether and/or how to bury the cables in areas of hard substrate.

These questions will be resolved when the cable developer is hired. The environmental impacts of the project will be addressed in the environmental impact statement ("EIS") for the proposed interisland cable.

The Department of Business, Economic Development, and Tourism would like to thank the University of Hawaii at Mānoa School of Ocean and Earth Science and Technology for their research hard work on this project.

2. Background

On October 20, 2008 the State of Hawaiʻi ("State") entered into an Energy Agreement between it and Hawaiian Electric which was signed by the Governor of the State of Hawaiʻi, the Department of Business Economic Development and Tourism (DBEDT), the Consumer Advocate, and Hawaiian Electric, on behalf of itself and its subsidiaries, Hawaii Electric Light Company, Inc. and Maui Electric Company, Limited (collectively, the "HCEI Parties").

The Energy Agreement commits the HCEI Parties to pursue a wide range of actions with the purpose of decreasing the State's dependence on imported fossil fuels through substantial increases in the use of renewable energy and implementation of new programs intended to secure greater energy efficiency and conservation.

In the Energy Agreement, Hawaiian Electric has committed to integrate and, with the assistance of the State, to accelerate the commitment for up to 400 megawatts ("MW") of wind energy into the Oʻahu electrical system (the "Interisland Wind Initiative"). The wind energy is expected to be produced by one or more wind facilities located on the islands of Lānaʻi and/or Molokaʻi and transmitted to Oʻahu and potentially Maui via an undersea cable (the "Interisland Cable").

With respect to the Interisland Cable, the State agreed to coordinate with developers, contractors, and/or Hawaiian Electric as the circumstances merit, on all matters related to the development of the Interisland Cable. The State delegated the responsibility of the Interisland Cable development to DBEDT. As lead agency for this effort, DBEDT's tasks include, but are not limited to, conducting or having contractors and/or consultants conduct the appropriate engineering and design of the Interisland Cable, assist with the acquisition and approvals of all necessary off-shore and on-shore land rights permits and approvals including the EIS.

The Interisland Cable, as envisioned, consists of an undersea transmission cable system with a minimum transfer capability of four-hundred (400) megawatts ("MW") to integrate either 1) the proposed two-hundred (200) megawatt wind facility on Lānaʻi and the two-hundred (200) megawatt wind facility on Molokaʻi with Oʻahu's electric grid; or, (2) possibly a single wind facility located on either Lānaʻi or Molokaʻi with Oʻahu's electric grid. A later phased cable extension to Maui is also proposed.

As part of this work effort, the State will draft a programmatic EIS for the Interisland Wind Initiative, with input from the wind developers on Lānaʻi and Molokaʻi and from HECO and MECO on Oʻahu and Maui. The wind developers are responsible for drafting their own respective Environmental Assessments and/or EISs for their individual wind farms. HECO and MECO are responsible for drafting their own respective EAs and/or EISs for the utility infrastructure upgrades on Oʻahu and Maui. The State is responsible for drafting the required environmental review documentation for the Interisland Cable.

Before proceeding with the considerable cost and work effort associated with the EIS for the Interisland Cable, DBEDT needed to first determine if laying a power transmission cable on the ocean floor between the islands Oʻahu, Lānaʻi, Molokaʻi and Maui was feasible from a physically standpoint. DBEDT contracted with the University of Hawaii at Mānoa, School of Ocean and Earth Science and Technology (UHM-SOEST) to compile all existing ocean floor data, to survey the gaps in the ocean floor data, and to recommend cable routes based on the survey results to facilitate this investigation.

The project was broken into two (2) discrete tasks with subtasks and sequential program review.

- **Task 1: Compile existing data regarding bathymetry, critical habitats, and seafloor; and,**
- **Task 2: Collect and process bathymetric and seafloor data**

The results of both tasks are described below.

3. Task 1

For Task 1, DBEDT asked UHM-SOEST to perform a desktop study to compile/process relevant existing ocean floor data, determine critical gaps in existing information, and recommend a program of new data collection and interface with DBEDT and its consultants, contractors and advisors on engineering and design parameters of the proposed cables and routes.

3.1. Compilation of Existing Data

As part of Task 1, UHM-SOEST made a digital compilation of publicly available bathymetry data gridded at 10 meters, for the seafloor area between O‘ahu, Moloka‘i , Lāna‘i and Maui. Figure 1 below in an example of the bathymetric data available as of April 30, 2009.

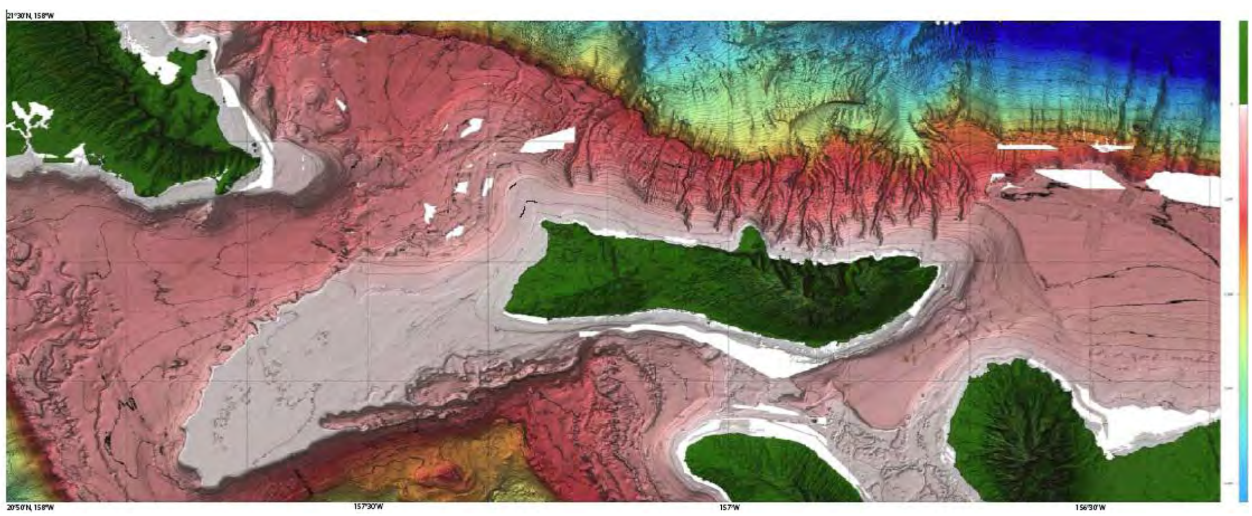


Figure 1 – Bathymetric data as of April 30, 2009

UHM-SOEST consulted with the State Office of Planning, which has an extensive GIS database, including marine layers (http://hawaii.gov/dbedt/gis/download.htm COASTAL/MARINELAYERS) that include the location of existing public submarine cables (http://hawaii.gov/dbedt/gis/cables.htm), the Hawaiian Islands Humpback Whale National Marine Sanctuary (http://hawaii.gov/dbedt/gis/sanctuary.htm) and other restricted/managed areas.

UHM-SOEST reviewed and collected data from the National Oceanic and Atmospheric Administration (NOAA) commissioned study which describes the near-shore benthic habitats in the main Hawaiian Islands. (See Figure 2). The benthic region begins at the shore line (intertidal or eulittoral zone) and extends downward out to sea. See NOAA National Centers for Coastal Ocean Science (NCCOS). 2007. Atlas of the Shallow-Water Benthic Habitats of the Main Hawaiian Islands. NOAA Technical Memoradum NOS NCCOS 61, Biogeography Team. Silver Springs, MD. 331 pp.

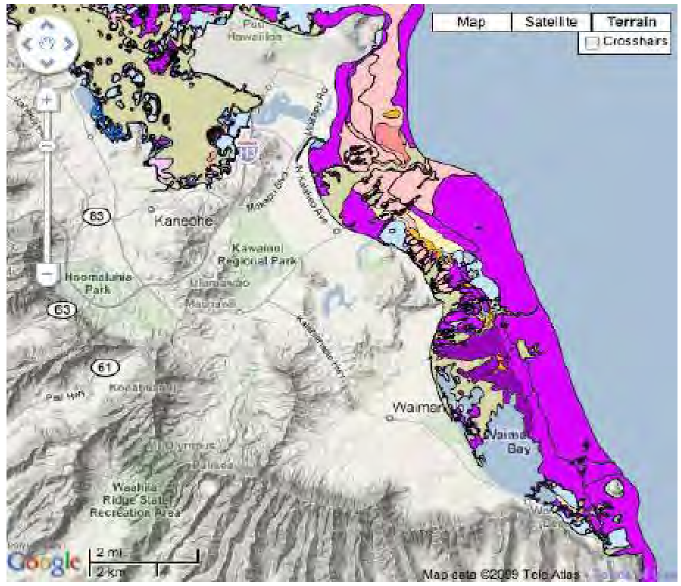


Figure 2- Near shore benthic habitat off of Kāneʻohe

UHM-SOEST reviewed and collected data from the United States Geologic Service studies of the benthic habitats offshore the south coast of Molokaʻi. (See Figure 3 and http://coralreefs.wr.usgs.gov/Molokaʻi.html).

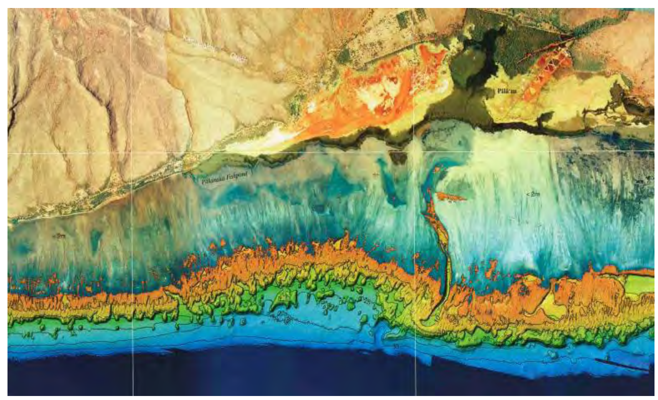


Figure 3 - Near Shore benthic habitat near south Moloka'i

UHM-SOEST also reviewed and collected data from 30 KHz sidescan sonar coverage offshore SE Oʻahu and north of Maui. (See Figure 4).

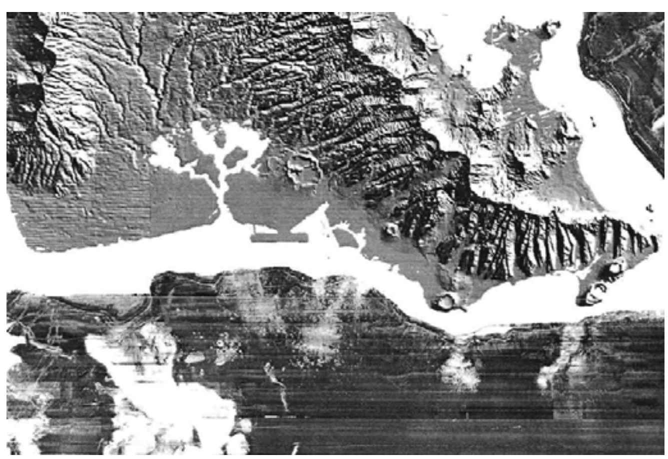


Figure 4 - 30 KHz sidescan sonar coverage offshore SE Oʻahu

3.2. Gap Analysis

Once the data collection was complete, UHM-SOEST determined it had bathymetry data covering ~95% of the study region (see Figure 1). Of the ~5% data gaps remaining, certain critical points including the shallow water areas east of Kailua-Makapuu, around ʻIlio Point NW Molokaʻi, south of central Molokaʻi, north of Lānaʻi, and north of Kahalui Maui that needed to be surveyed in order to better define the recommended and alternate undersea cable routes between Oʻahu, Lānaʻi, Molokaʻi and Maui.

3.3. Cable Landing Sites

Cable routes are uniquely prescribed by their end points. The final landing sites for the cable will be selected after the environmental review for the Interisland Wind and Interisland Cable project are complete. Sites needed to be identified however, in order to conduct the ocean floor survey. DBEDT asked UHM-SOEST to consider landings at Pearl-Honolulu Harbor and Kāneʻohe (to connect to the ʻIwilei and Koʻolau sub-stations) on Oʻahu, NW Molokaʻi and north Lānaʻi (to connect to proposed wind farms), and south Molokaʻi (as part of a possible land-sea route between NW Molokaʻi and Lānaʻi). Where underwater cables would best link to the Maui electric grid has not been determined. Therefore the candidate sites on NW Maui and near Kahalui are provisional.

3.4. Technical Cable Requirements

Following the collection of data, UHM-SOEST met with DBEDT and its consultants to determine the following key parameters for the proposed undersea power cables:

- High voltage, direct current cables are recommended for the size (~400 MW) and length of submarine cables (>20 miles) envisioned.
- Existing (double armored) cable technology and laying techniques (direct lay or buried) can be utilized at ocean depths to 800 m.
- For cable protection, burial 1-2 m sub-bottom is desirable in water 100 m or shallower, and may be considered for all water depths.
- Cables should be routed to avoid steep slopes, sharp changes in slopes, suspended spans, or bending radii less than 6 m. Cables can be lain on slopes up to 30 degrees, and up to 45 degrees with cable anchoring.
- Directionally drilled micro-tunnels used in shore areas to minimize impacts can be up to 1.5 km long.

3.5. Initial Cable Route Suggestions

Based on the desk-top study and gap analysis, the technical cable requirements, available information on proposed sites for cable landings and converter stations, and it's knowledge of marine geology, benthic biology and oceanography, UHM-SOEST developed a set of initial submarine cable routes and alternatives.

Principles that guided UHM-SOEST's recommended routes included:

- minimize distance (given cost of cable);
- keep depth above 800 m (for better navigation and less weight of cable during laying);
- minimize length in whale sanctuary and other marine protected/restricted areas;

- minimize crossing of steep slopes, hard grounds, important benthic habitats, precious corals and dumped materials;
- minimize crossing existing telecom cables; and,
- prefer crossings at high angles.

From existing data UHM-SOEST recognized numerous constraints, including:

- no viable route north of Molokaʻi given the submarine canyons and landslides;
- connecting Molokaʻi, Lānaʻi, and Maui will require cables in the whale sanctuary;
- offshore areas less than 120-m-deep were sub-aerially exposed and eroded during the last glacial maximum 20,000 years ago;
- during subsequent sea level rise, modern coral reefs grew and now fringe all the islands;
- living (including precious) corals and extremely rugged seafloor dominate between east Lānaʻi and west Maui – Kihei;
- generally steep edges of Penguin Bank and Oʻahu approaches;
- no viable route across SE Penguin Bank (rugged and steep paleo-reef slopes);
- deep former reefs occur in some places between the islands; and,
- material dumped south of Pearl and Honolulu Harbors.

Using these criteria and the data collected previously, UHM-SOEST developed nine (9) possible routes shown in Figure 5.

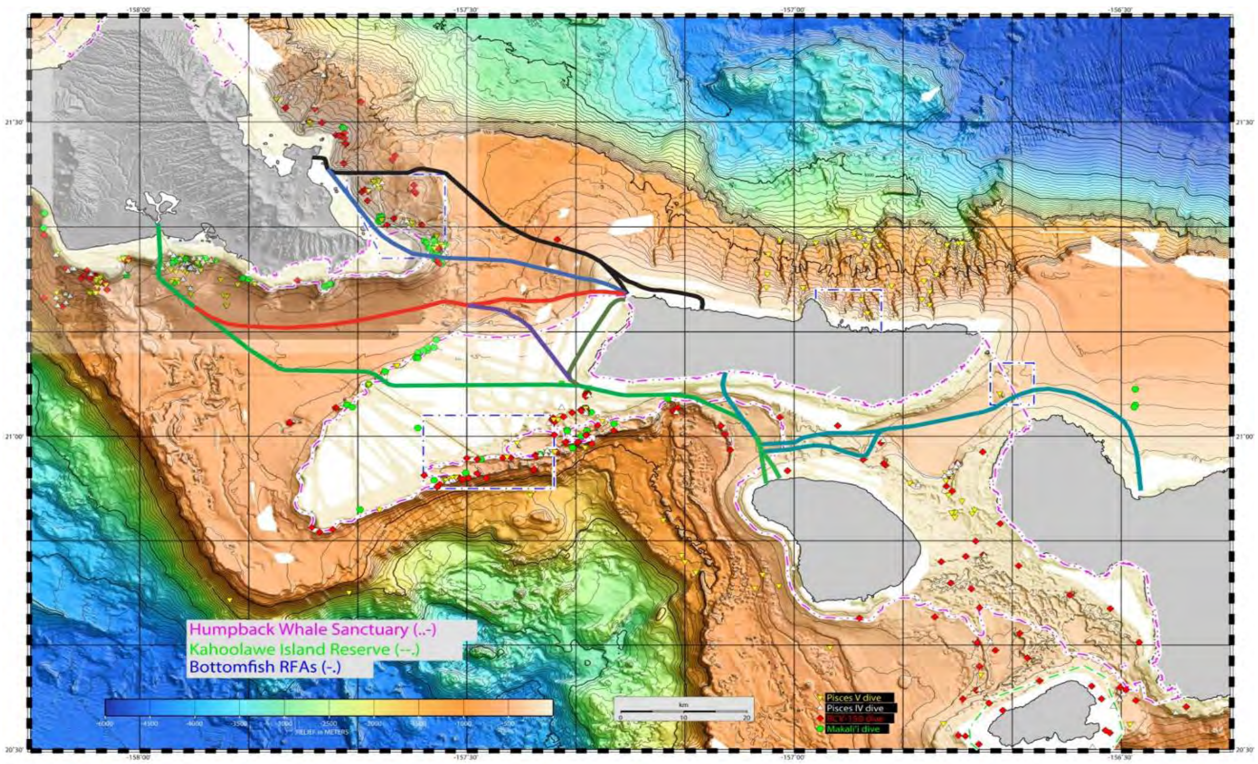


Figure 5 - Initial Cable Route Suggestions

4. Task 2

For Task 2, DBEDT asked UHM-SOEST to collect and process and analyze uncharted bathymetric data, sidescan, seafloor sampling and video of the targeted seafloor along the possible routes identified in Task 1. (See Figure 5). For this task DBEDT also asked UHM-SOEST to recommend routes for the Interisland Cable between Oʻahu, Lānaʻi, Molokaʻi and Maui based solely on the information gathered. The route recommendations were to be based on analyses of seafloor characteristics, bathymetry data, video and interface with DBEDT and its consultants, contractors and advisors on engineering and design parameters of the proposed cables and routes. Task 2 was broken down into the following sub-tasks:

- Task 2a: Collect and process new bathymetric data of nearshore Lānaʻi and south of Molokaʻi.
- Task 2a: Determine the initial recommended and alternative routing corridor for the undersea cable between Oʻahu, Molokaʻi , Lānaʻi and Maui based on the new and existing bathymetric data, along with landing sites on Oʻahu, Molokaʻi , Lānaʻi, and Maui.
- Task 2b: Based on the recommended and alternative routes for the cable perform a combination of sidescan/subbottom profiling along the seafloor between the islands.
- Task 2b: Based on the sidescan/subbottom profiles, determine what changes need to be made to the recommended and alternative routing corridor for the undersea cable between the islands.
- Task 2c: Based on the amended recommended and alternative routing corridors of the undersea cable, perform camera/video surveys of the seafloor and seafloor sampling along various points along the route.
- Task 2d: Prepare a Task 2 technical final report detailing the steps taken to determine the recommended and alternative routes for the undersea cable and provide GIS maps of the final recommended routes and alternatives.

4.1. New Data Collection

To develop the initially proposed routes and alternatives, UHM-SOEST collected new data that included (1) shallow water multibeam bathymetry mapping (using the 25’ NOAA survey launch R/V Ahi) to fill the existing shallow water (<200 m depth) data gaps around where the cables may be routed, and (2) cruises of R/V Ka’imikai-O-Kanaloa (see Figure 6) that surveyed along the proposed cable routes using deep-towed sub-bottom profiling and sidescan, camera/video transects, and seafloor sampling at various points. (See Figure 7).

Figure 6 – R/VAhi and Ka'imikai-O-Kanaloa, ROV video camera, Deep tow Sonar, and Tow Cam and Magnetometer

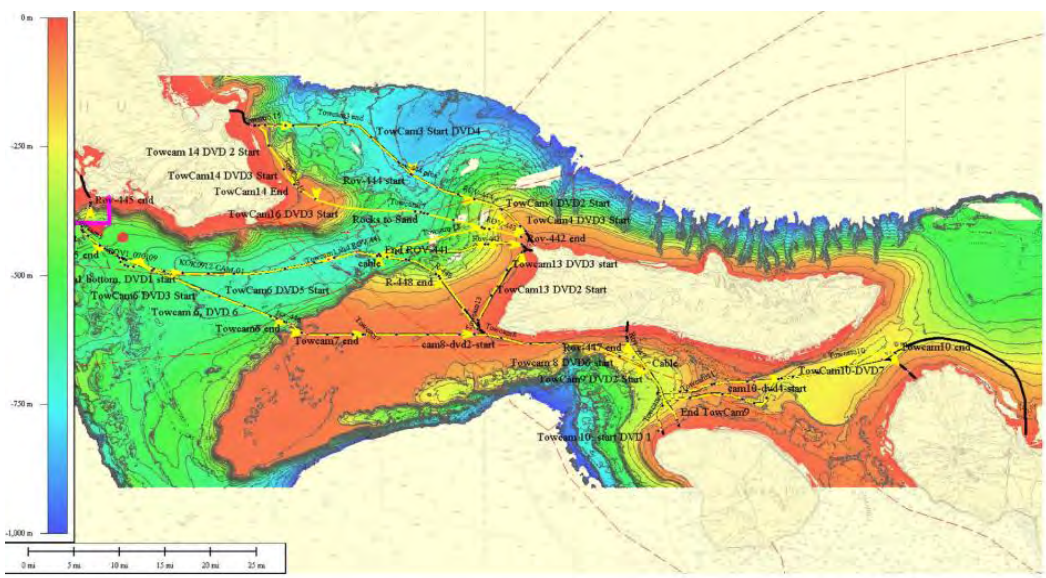


Figure 7 Camera/Video Surveys

Additional swath bathymetry data from an independent two-day R/V Kilo Moana (Figure 8) cruise in July was also added to fill deeper water data gaps, resulting in a nearly complete grid of swath bathymetry, and one that fully covers all the considered cable routes.

Figure 8 R/V Kilo Moana

Detailed near-shore surveys to better characterize the shallow-water substrate will be performed when the exact landing sites are determined.

4.2. Recommended submarine cable routes and alternatives

Following analysis of the new and existing information, UHM-SOEST recommended and identified alternate undersea cable routes between O‘ahu, Moloka‘i , Lāna‘i and Maui, based on the discussion and data interpretation that follows. An integrated ARC-GIS project volume of the seafloor data, together with the recommended routes, accompanies this report (the sub-bottom profiles, core descriptions, magnetometer and CTD profiles are in separate files, previously supplied). Priority was given to determining viable routes where the cable may be laid.

The areas where the cable may be buried or covered, and at what cost, remains to be determined. The issue of burying the cable will be looked at in greater detail in the forth coming environmental review for the interisland cable project.

4.3. Routes to Pearl-Honolulu Harbor

For the proposed inter-island power cable to reach the ‘Iwilei sub-station in Honolulu they have to cross the wide coral reef along the south O‘ahu shore. Five reef crossings have been dredged previously (Figure 9), the three deepest being the entrances to Pearl Harbor, Ke’ehi Lagoon and Honolulu Harbor, the two others being at either end of the Honolulu airport runway.

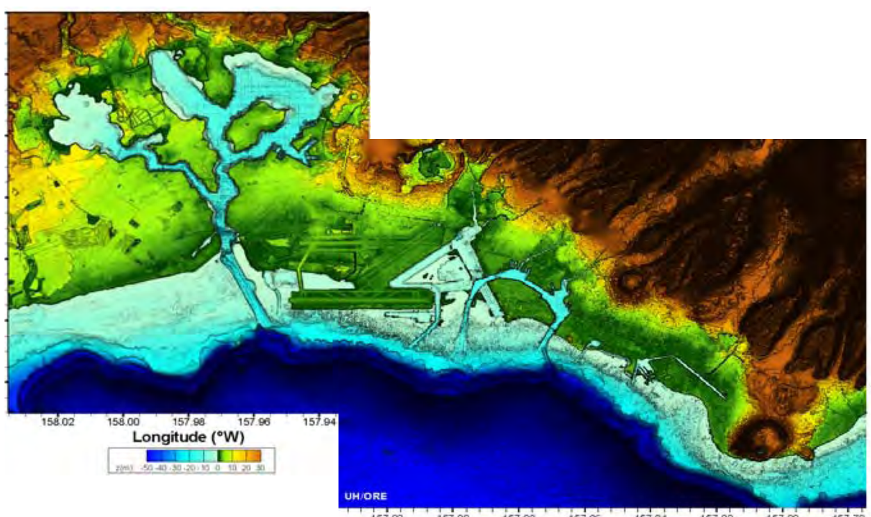


Figure 9 – Honolulu and Pearl Harbors

Dredged materials from these and other excavations (e.g. Ala Wai canal), plus several man-made materials and munitions, have been dumped over the years to the south of Oahu. See Figure 10.

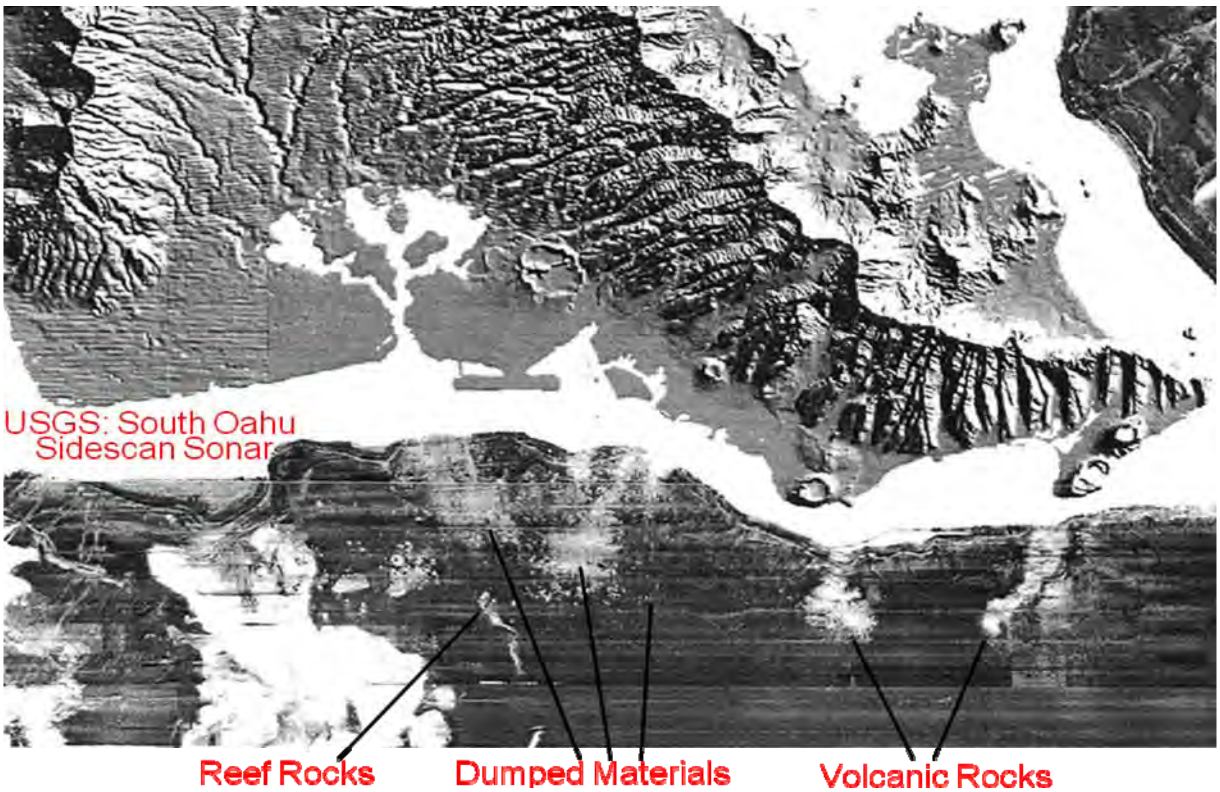


Figure 10 Dump material south of Honolulu Harbor

UHM-SOEST recommends the undersea cables should avoid, to the extent possible, this region of dumped materials by routing the cables to the east or to the west of the large concentration of debris that occurs south of Honolulu airport. Either choice does not obviate the need for careful placement to avoid less concentrated debris and munitions scattered further away. UHM-SOEST recommends the western route to avoid high concentrations of debris immediately south of the Honolulu Harbor entrance, to keep the submarine cable away from the high-use areas offshore Waikiki-Kaka'ako, and to not impede plans for future seawater A/C (and other) pipes off Honolulu-Waikiki.

A cable laid to the entrance of the Pearl Harbor dredged channel could be routed ashore to the converter station, and another cable from there to the Iwilei substation, in several ways in part depending on the desired location and permitting of the converter station. This route could involve a combination of underwater segments (e.g., the various dredged channels, the submarine terrace south of the reef runway, through Ke'ehi lagoon, and under Sand Island Bridge to west Honolulu Harbor) and/or subaerial segments (e.g., edge of reef runway, Pearl Harbor military base, H1 right-of-way). The identification of these terrestrial and amphibious alternatives is beyond the scope of DBEDT/UHM-SOEST contract.

4.4. Pearl Harbor/Honolulu Harbor to Lānaʻi

The UHM-SOEST recommended cable route between Pearl and Honolulu Harbor and Lānaʻi trends SSW from the entrance of the Pearl Harbor dredged channel down the slope, with minor course changes to avoid obstacles identified in the sidescan sonar and bathymetry. (See Figure 11). The sub-bottom profile shows no significant sonar penetration, indicating a compact/hard substrate. At the base of slope (~400 meters water depth) the route curves to the southeast (to avoid the paleo-reef further south and west) and then east.

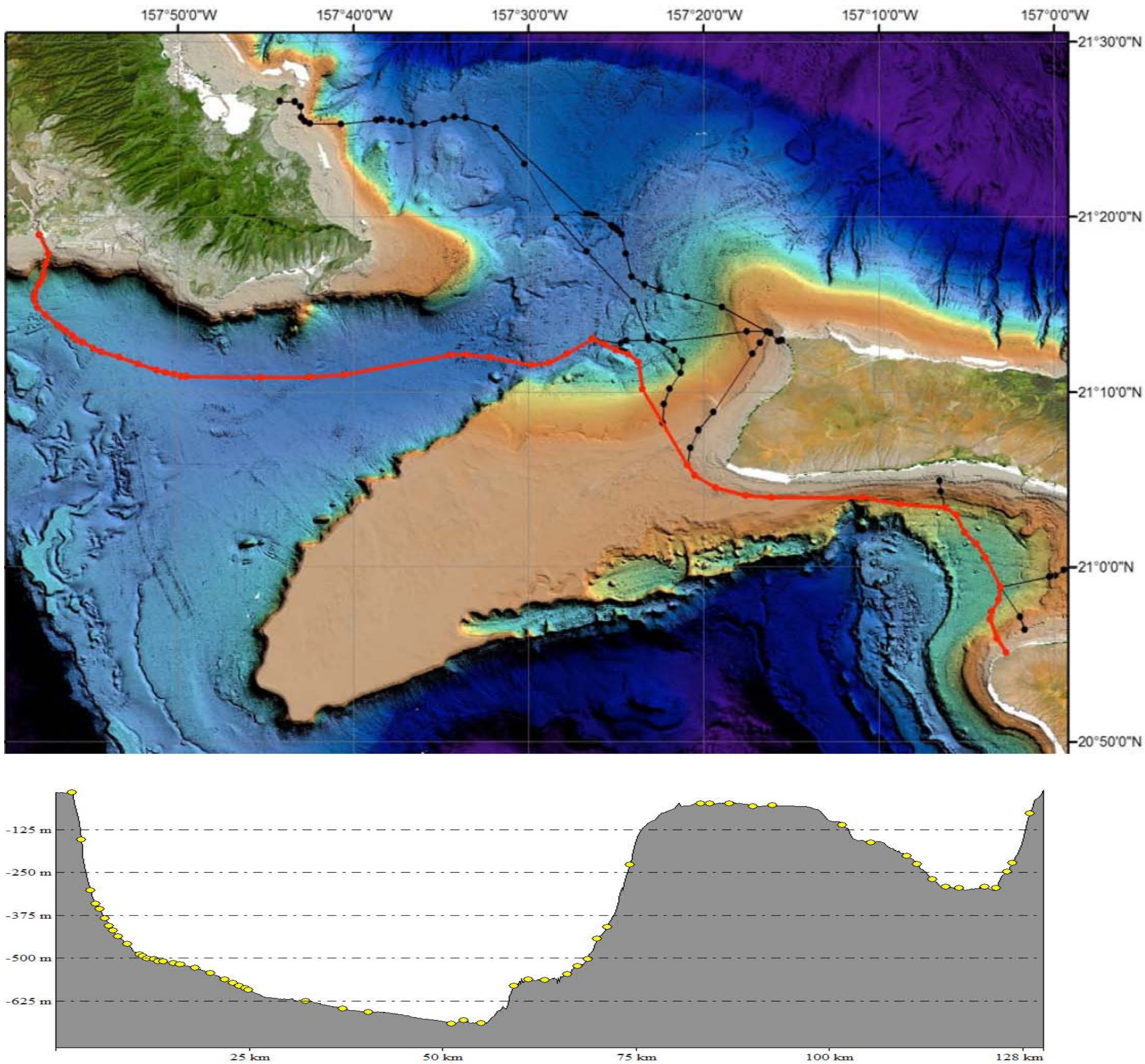


Figure 11 - Pearl-Honolulu to Lanai

The route stays south of the main dumping fields and just north of a telecom cable (that may have become buried, UHM-SOEST did not see it in sidescan or video). Here the profile shows significant sub-bottom reflections and gravity coring penetrated ~1m of sandy mud, indicating good potential to bury a cable. This route weaves between a myriad of dumped materials and munitions that litter the seafloor until passing east of Diamond Head.

Oʻahu and Molokaʻi were once connected by surrounding coral reefs in much the same way as Lānaʻi and west Maui are today. That former reef edge is now at depths of 650-750 m in the Kaʻiwi Channel. The recommended cable route continues east with good sub-bottom reflectors until crossing the former reef edge. Thereafter sub-bottom reflectors are observed only intermittently and the substrate is often compact/hard.

The recommended route avoids outcrops and scours seen in the sidescan and rises up onto Penguin Bank at a place where the slope is less steep than further west, and via a sloped channel that is more easterly of the route originally considered. On top of Penguin Bank, to the west and south of Molokaʻi, the substrate is compact/hard. Gravity core catchers returned carbonate sand and gravel, but there was no significant core penetration. There is a sand dune field off the SW corner of Molokaʻi. (See Figure 12).

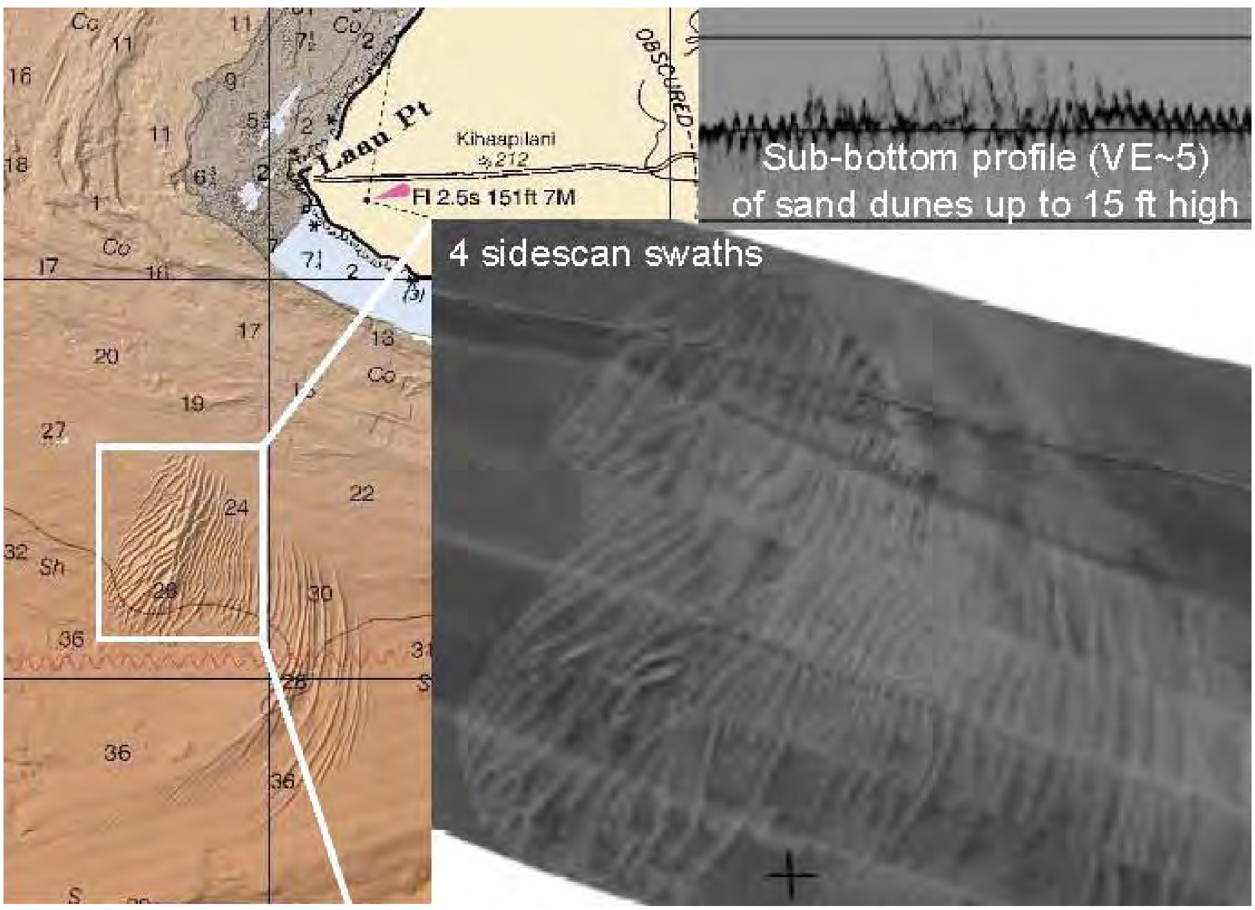


Figure 12 – Sand Dunes off the SW Corner of Molokaʻi

The route continues east, staying south of the Molokaʻi's fringing coral reef and north of an existing telecom cable, submarine canyon head and paleo-reef complex. The narrow corridor between these bounding features is a critical path and choke point for all the recommended cable routes connecting Oʻahu, Molokaʻi and Lānaʻi. Curving to the SE and then south, the route crosses a terrace at ~300 m depth with good sub-bottom reflectors (although poor core recovery of sandy mud) before climbing the slope up to NW Lānaʻi where there are sandy beaches and a narrow fringing reef.

4.5. Kāneʻohe to NW Molokaʻi

The recommended cable route from Kāneʻohe to NW Molokaʻi lands at Kāneʻohe Marine Air Station on Oʻahu where a cable could be run along the H3 right-of-way to the Koʻolau substation. (See Figure 13). Near shore to the east there is a 2 kilometer wide reef terrace. Along part of this route the substrate remains thinly sedimented over reef rock until passing around the submarine canyon head east of Kailua and down off the shelf. Coring the slope recovered 1 meter of silty mud.

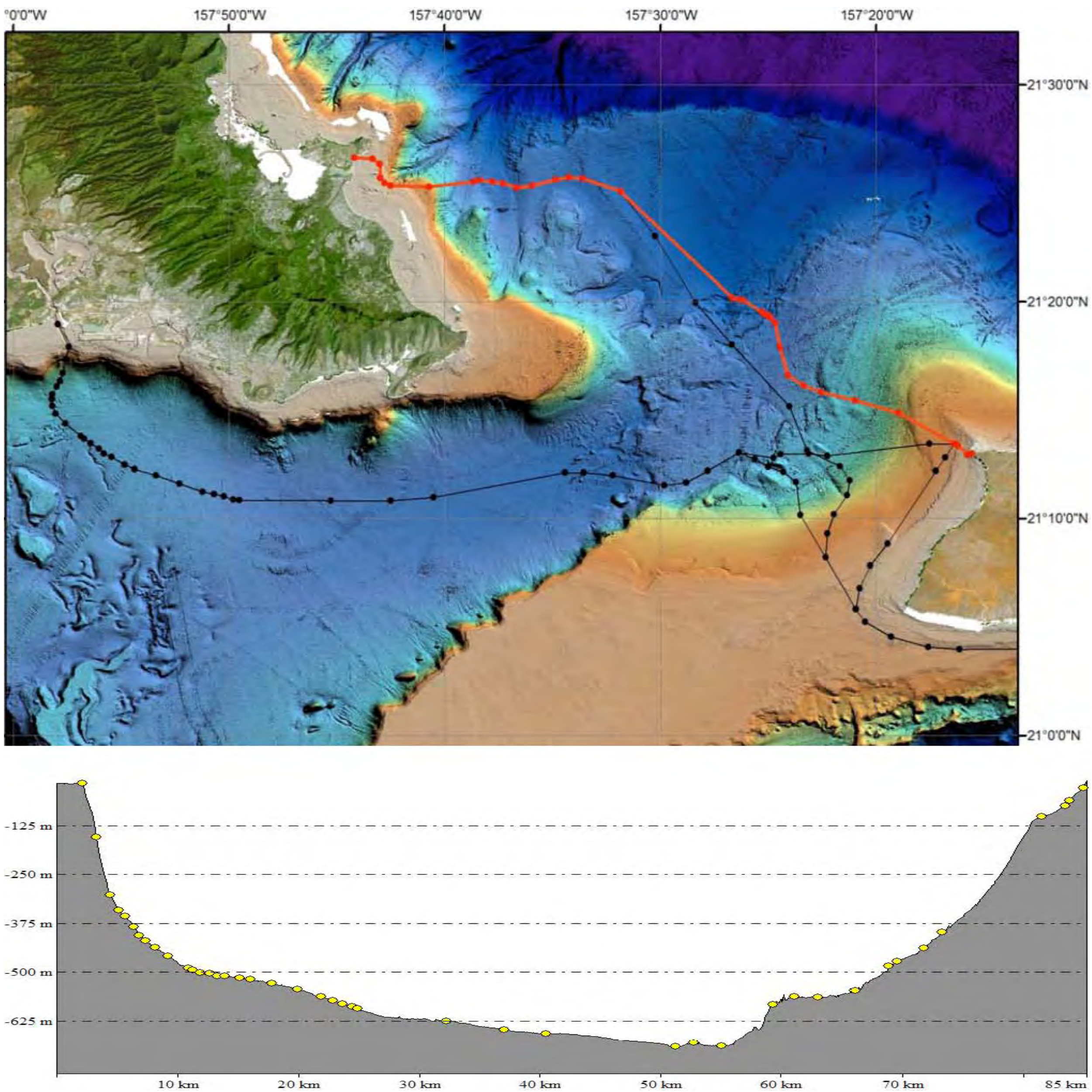


Figure 13 - Kāneʻohe to NW Molokaʻi

The easterly route crosses low-relief channels coming off Waimanalo and stays north of the bottom fish refuge until turning around it (and associated deep former reef) to the SE. The 700-800-m deep flat area has good sub-bottom reflectors (though core recovery of the carbonate mud-silt-sand was spotty). These reflectors end when the route crosses onto a deep former reef to the SE. The route weaves around rock outcrops seen in the sidescan and up the slope to NW Molokaʻi. Sidescan indicates that the shelf north of north west Molokaʻi is hard reef substrate, with rugged karst in places. To avoid the worst of this, the route comes in from the WNW towards ʻIlio Point, crosses a low point in the relict reef edge, then trends SE to where the modern reef is narrowest (allowing the cable to pass underneath in a micro-tunnel). At the coastal end of a dirt road there is a sandy landing site. A cable right-of-way could pass along the dirt road to the proposed wind farm further east. (See Figure 14).

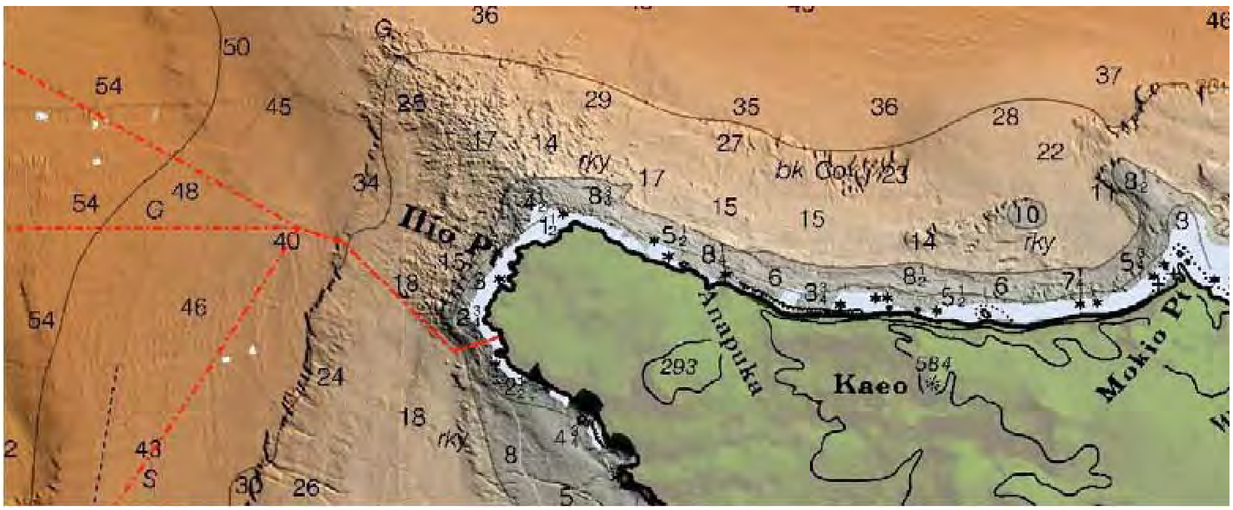


Figure 14 - ʻIlio Point on NW Molokai

4.6. NW Molokai to Lanai

The route from ʻIlio Point retraces the same route that comes from Kāneʻohe, before turning SW to parallel the west Molokaʻi shore where it stays below the relict reef edge in muddy (low backscatter) sediments identified on the sidescan. The mud field ends to the SW and the route passes onto the compact sand with dunes that characterizes the current-swept top of Penguin Bank. Off SW Molokaʻi the route merges with that from Pearl Harbor to Lānaʻi. Almost the whole route is within the Humpback Whale Sanctuary. (See Figure 15).

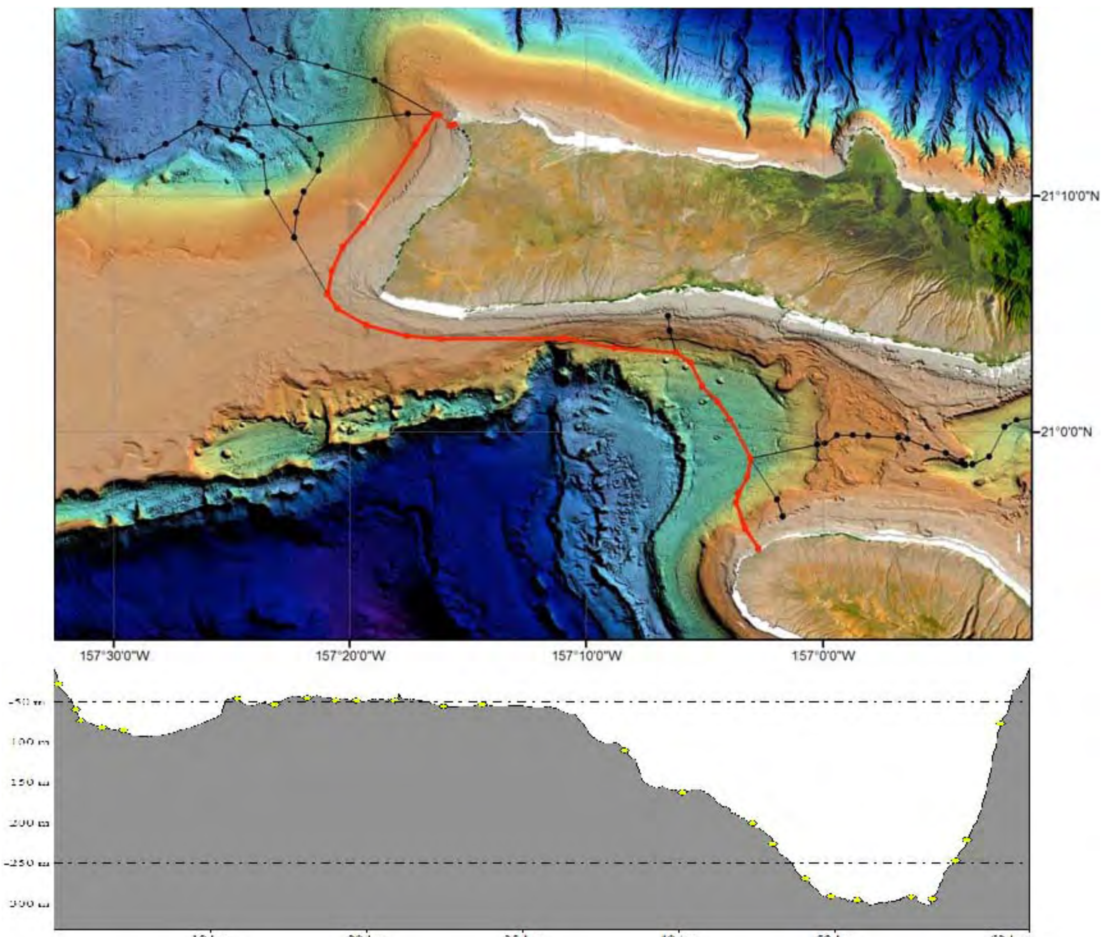


Figure 15 - NW Molokaʻi to Lānaʻi

4.7. O‘ahu to Moloka‘i /Lāna‘i to Maui

The recommended routes linking O‘ahu-Moloka‘i-Lāna‘i can be extended within the whale sanctuary east to Maui, but there are two areas where particular care will be required. The first is crossing the relict reef in the Kalohi Channel between Moloka‘i and Lāna‘i, particularly its steep east and west edges. Two alternative routes were investigated to cross this, and the recommended route is a variation and combination of them both. It uses the northern of the two small channels originally identified to cross the western reef edge. But the new swath bathymetry and deep-towed sidescan data show that the steep eastern edge can’t be traversed exactly where surveyed. Rather, UHM-SOEST proposed a route across the SE nose of the relict reef, where the slope is gentler, to link up with the southern route. The only other passage off the relict reef to the thickly sedimented floor of the Pailolo channel is slightly further south along the axis of a steep-sided, E-W-trending, narrow chute whose floor is only ~50 m wide in the west where it rises up onto the relict reef platform. That platform is current swept and thinly sedimented reef rock, with no sub-bottom reflectors.

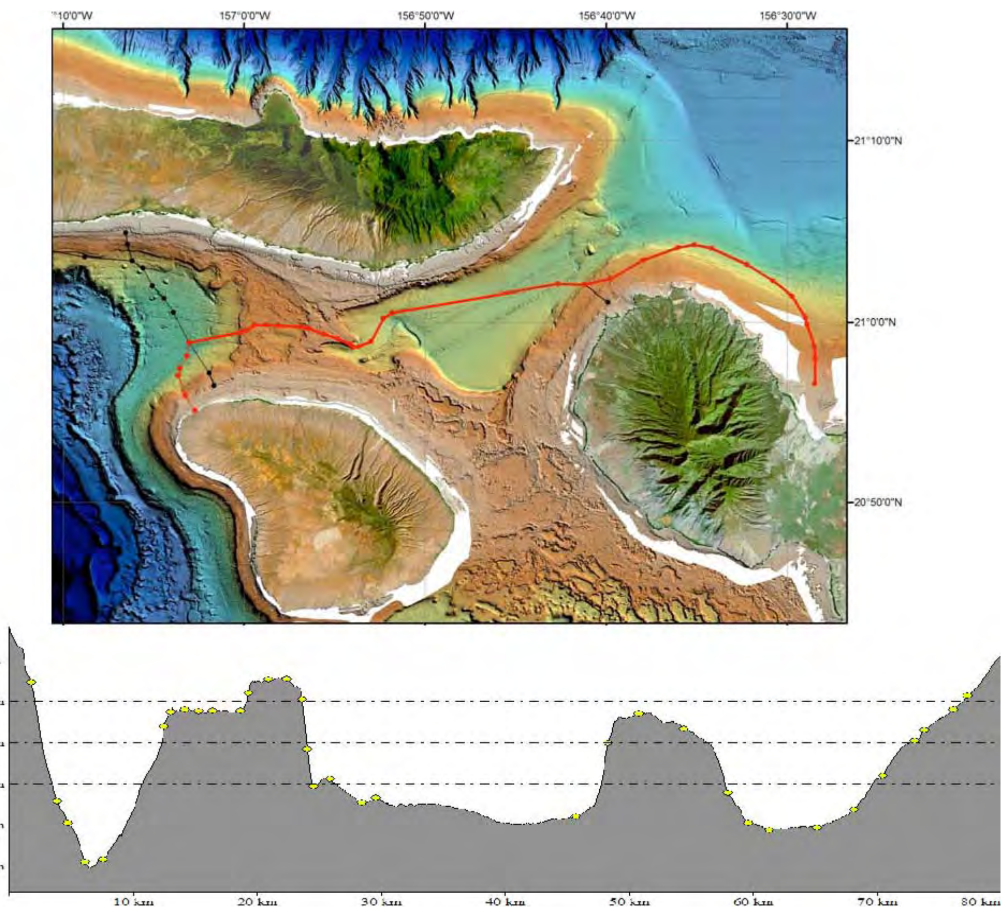


Figure 16 – Oahu – Moloka‘i - Lāna‘i to Maui

The ~270-300-m deep central Pailolo channel has good sub-bottom reflectors in sandy sediments east of where the surveyed route to Maui branches, NW of Kapalua. Another submerged relict reef is encountered there and to the NE with rough rocky seafloor and supporting a benthic fishing reserve. (See Figure 17).

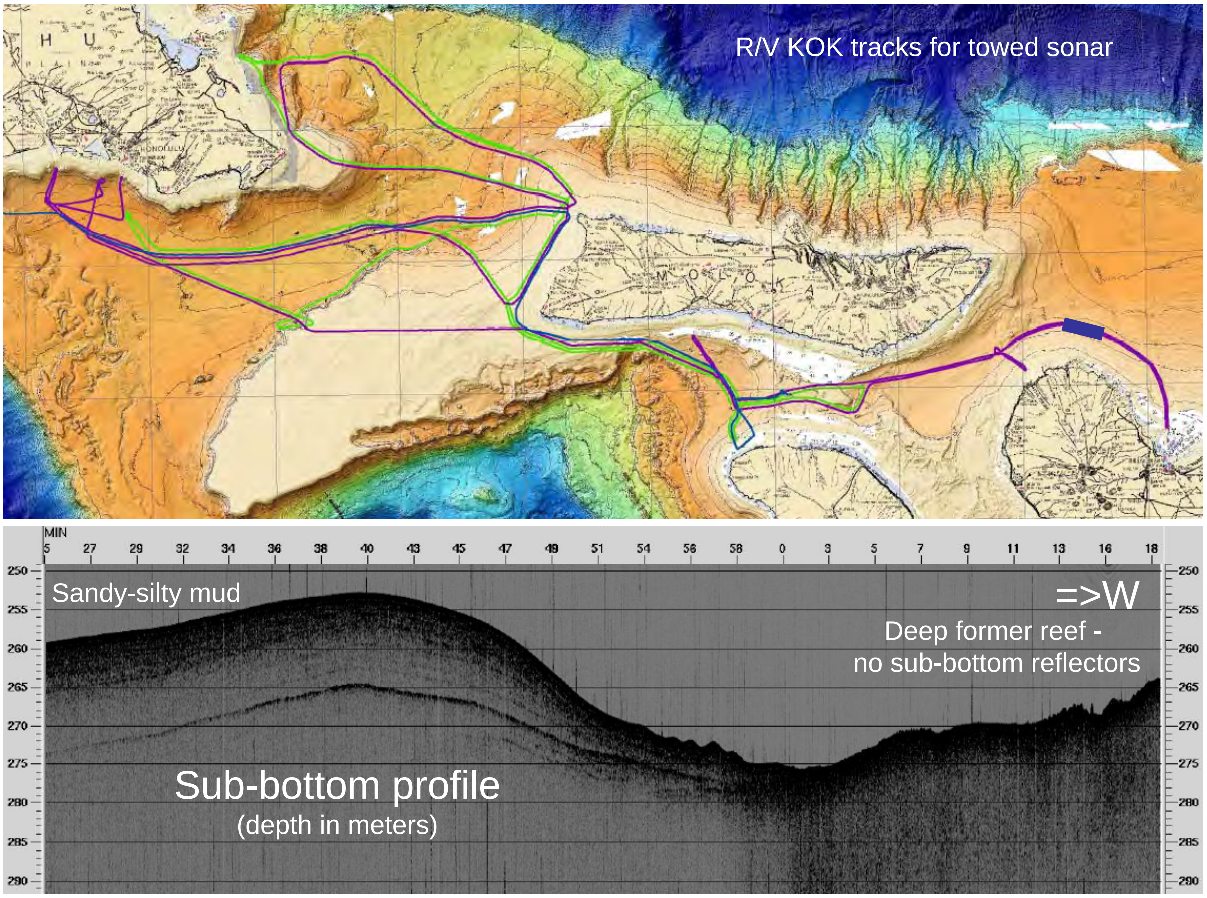


Figure 17 - Substrate north of Maui

Based on USGS 30 kHz sidescan, and swath bathymetry, UHM-SOEST moved the recommended cable route to Kahalui south of the BFRA and closer to west Maui (where the seafloor acoustic returns are weaker) until it passes into the area of good sub-bottom reflectors and muddy sand NE of west Maui, and then turns south to Kahalui. The surveyed spur route towards Kapalua, west Maui, is a viable and shorter alternative, depending on whether a converter station could be established on the narrow coastal strip and efficiently linked to the electricity grid.

4.8. Alternative Routes

If a land-sea cable route from NW Molokaʻi to Lānaʻi is contemplated, then a possible alternate route from south Molokaʻi would be under/across the 2 kilometer wide reef offshore Pala’au or Hale’o’lono and then SSE to Lānaʻi. (See Figure 15 or 19). To combine with that route, UHM-SOEST surveyed and include an alternate route from Pearl-Honolulu Harbor to NW Molokaʻi. The route follows the route from Pearl Harbor to Lānaʻi until, instead of turning SE, it continues east up the west Moloka‘i slope to ‘Ilio Point. On much of that slope, the sub-bottom profile shows no significant penetration, indicating a compact/hard substrate.

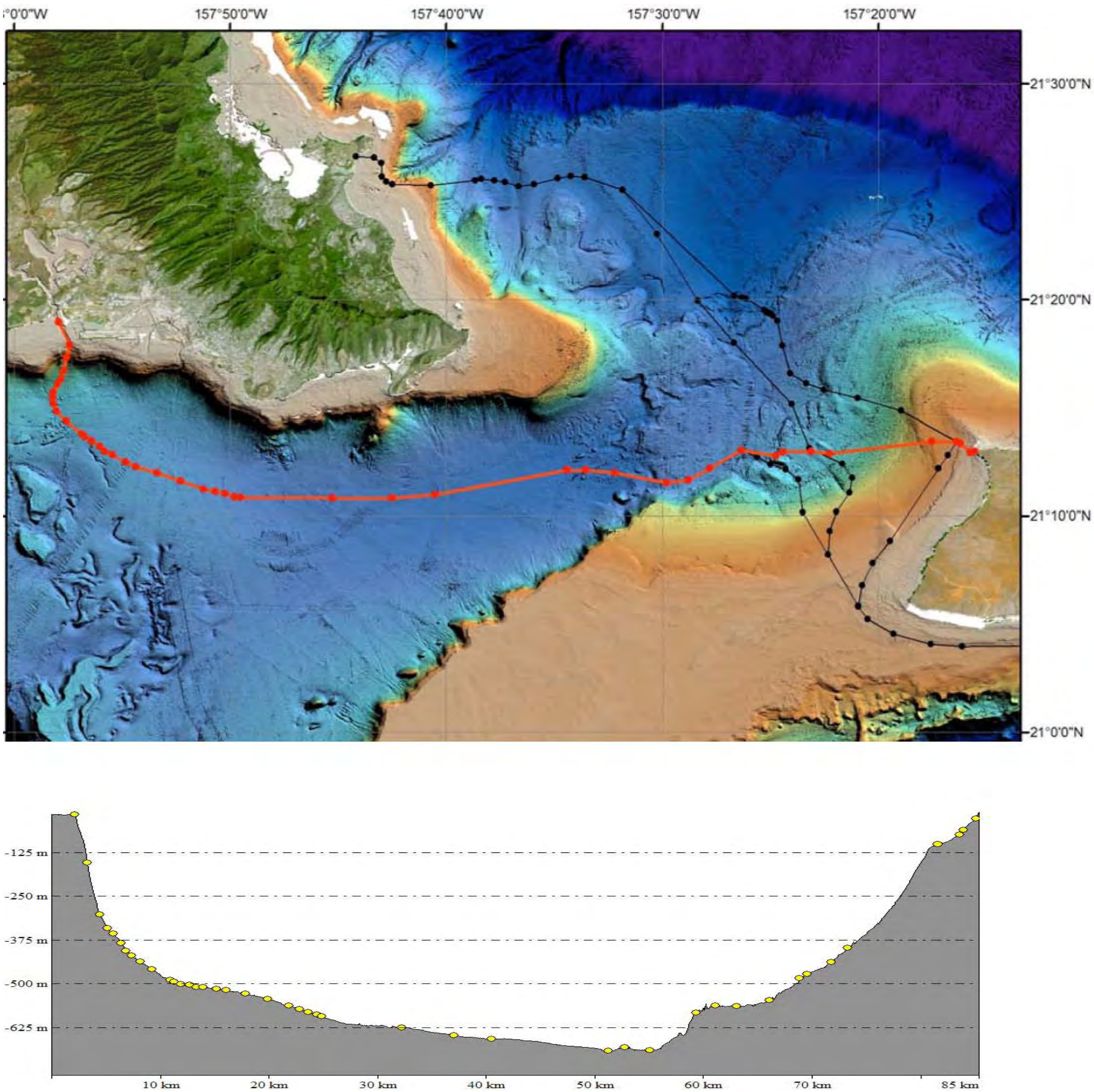


Figure 18 - Pearl/Honolulu to Moloka‘i

If, for whatever reason, cable landings at NW Moloka‘i are excluded then, based on swath bathymetry and acoustic imagery, UHM-SOEST recommends an alternate route from Kāne‘ohe directly to Lāna‘i that joins the two recommended routes from Kāne‘ohe and to Lāna‘i with a SE-trending segment across the deeper relict reef areas at the foot of slope west of Moloka‘i. UHM-SOEST predicts a hard substrate along much of the joining segment.

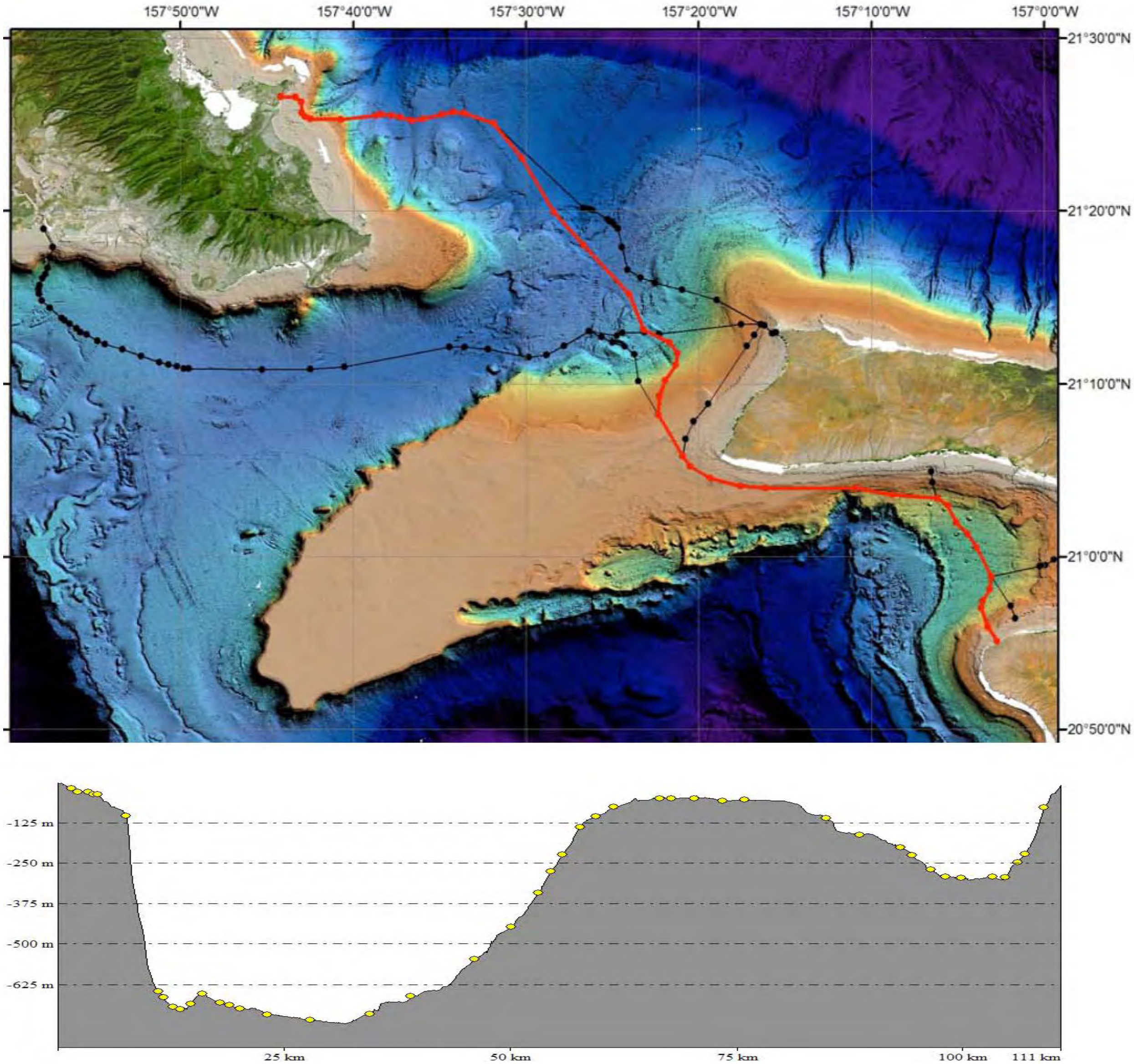


Figure 19 - Kāneʻohe to Lānaʻi

4.9. Routes not recommended

The Pearl Harbor to Lānaʻi cable route east across Penguin Bank is not viable because of the steep western edge of Penguin Bank. UHM-SOEST surveyed potential crossing points along the western steep edge, but only found vertical cliffs and boulder-strewn channels that would prevent cable laying. Although somewhat shorter, this route also entails longer stretches in the Humpback Whale Sanctuary.

The Kāneʻohe to NW Molokaʻi cable route considered along the Waimanalo-Makapuʻu Shelf is subject to intense fishing and anchoring, crosses the SE Oʻahu portion of the Humback Whale Sanctuary as well as precious coral beds on the slope east of the Makapuʻu Shelf, which has a hard substrate with numerous rock ledges. This route is not recommended.

5. Existing seafloor cables

The reported positions of existing seafloor cables are not always reliable. (See figure 20, but note that the route alternatives are those initially proposed, not the final ones).

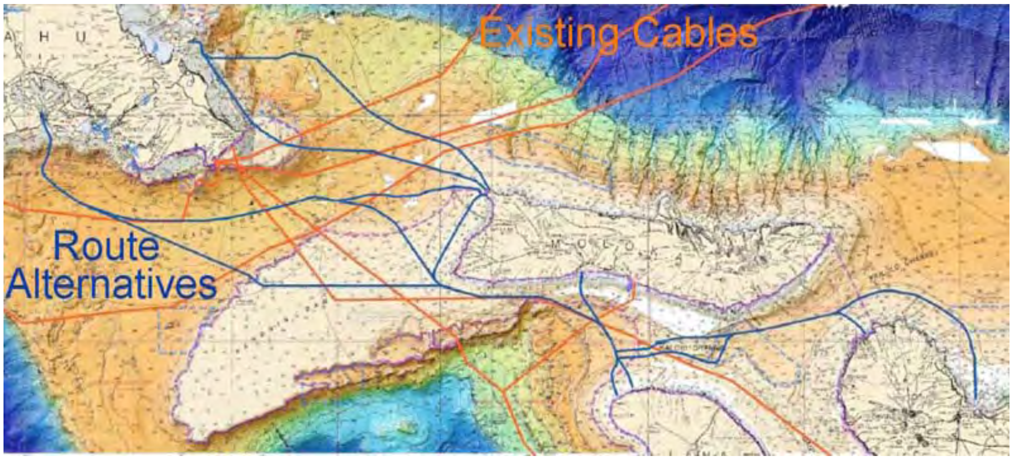
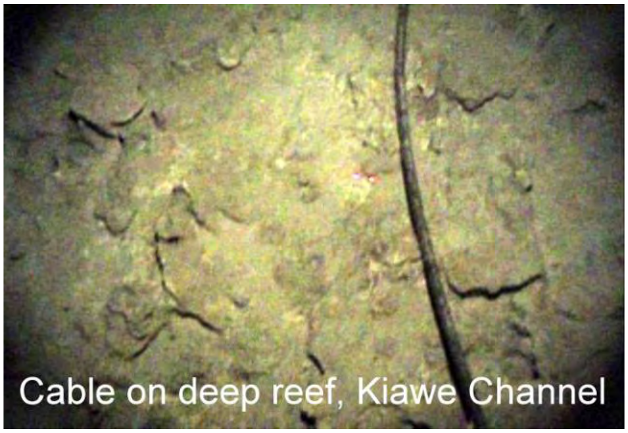


Figure 20 - Existing cables in red

Figure 21 below also shows the reported location of cables (light pink lines) and where actually seen (indicated by a red dot - linked to a corresponding video frame in the ARC-GIS project volume accompanying this report – such as that at right). Inspection reveals that some cable crossings are quite close to their reported positions, whereas others are not. Other supposed cables were crossed without evidence (possibly buried in sediment), and some unknown cables were seen.



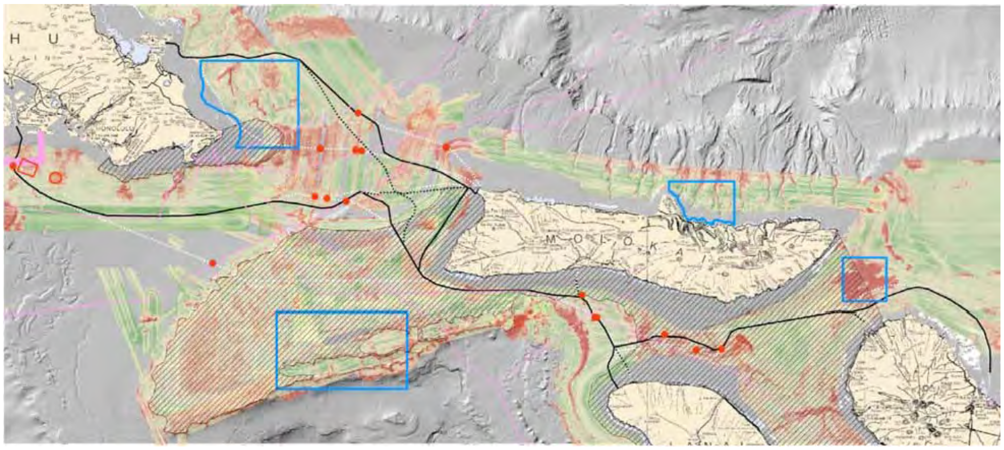


Figure 21 - Cables identified

Some portions of existing cables can also be identified in the deep-towed sidescan (e.g., south of west Moloka‘i). Also shown on Figure 21 above are the recommended (black) and alternate (dashed) cable routes, other routes surveyed (white dashed), on sunlit bathymetry (gray) and seafloor acoustic imagery (red = strong, green = weak). Blue boxes are bottom fish refuges; ruled areas are the Humpback Whale Sanctuary.

6. Cable burial

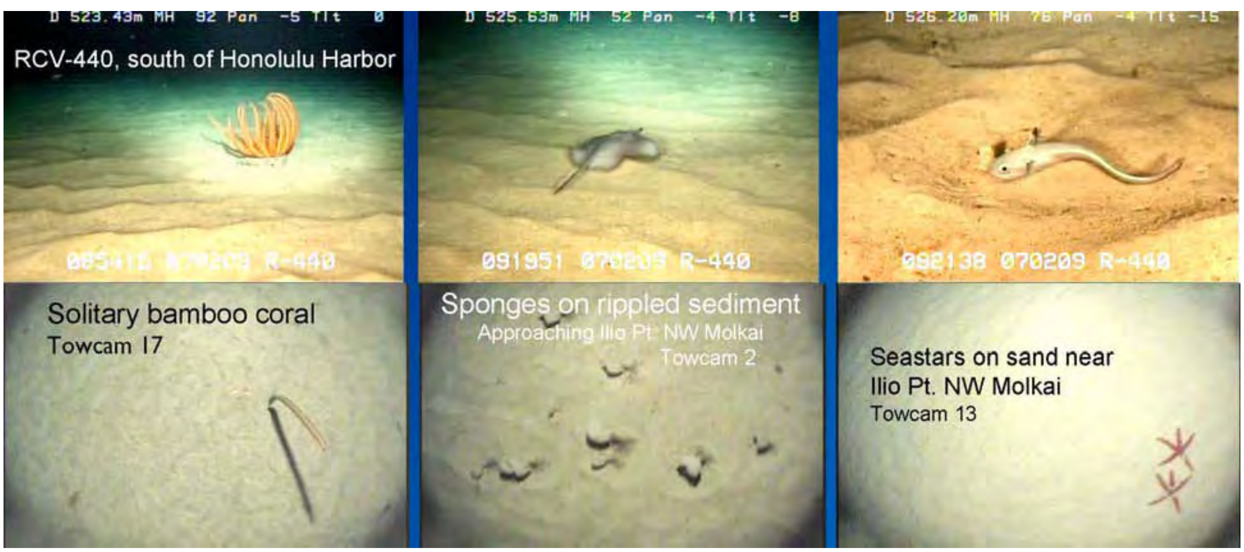
Sub-bottom profiling and coring reveal that only the deeper water areas have a muddy seafloor substrate that would readily facilitate burying the proposed interisland cable. This mud typically contains 20-30% sand. These areas include the deep water Ka‘iwi channel south of O‘ahu, the deep water area east of Waimanalo, the terrace at ~300 m depth between Moloka‘i and Lāna‘i, the central part of the Pailolo channel between Moloka‘i and Maui, and NE of west Maui approaching Kahului.

In contrast, the shallow water areas surrounding the islands, where cable burial may be most desired, have a hard substrate of active/relict coral reef and/or compact sand. Areas of relict reef rock are also identified in some deep-water areas of the interisland channels and slopes.

The environmental review for the Interisland Cable project will further investigate the impacts caused or avoided by burying the Interisland Cable, and will also consider other alternatives to cover the cable to better protect it and the marine environment.

7. Benthic macro fauna

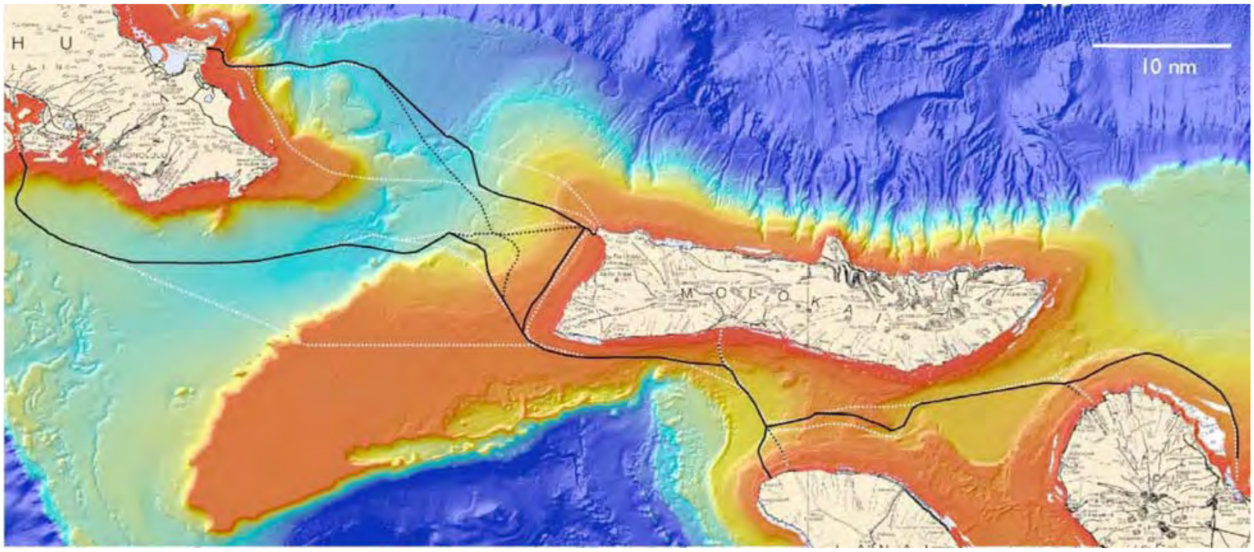
Beyond the shallow reefs, benthic macro fauna (e.g., fish, rays, seastars, urchins, seapens, and sponges) are sparsely observed on the video tows and ROV dives along the proposed routes.



Exceptions to this generally occur in the precious coral beds on the slope east of the Makapu’u Shelf and along the easterly transect across Penguin Bank. The two somewhat shorter routes originally considered to cross these benthic habitats, both of which entail longer stretches in the Humback Whale Sanctuary, are not recommended.

8. Summary

From previous and newly acquired ocean floor surveys UHM-SOEST has identified a set of inter-island routes where underwater power cables may be laid to connect Oʻahu, Molokaʻi, Lānaʻi and Maui.



The routes avoid the bottom fish refuge areas. They minimize but can't eliminate segments within the Humpback Whale Sanctuary, and cross areas of hard substrate and fringing coral reefs. Challenges remain, including:

- precisely laying the cables around deep-water obstacles, such as former reefs, dumped materials and munitions;
- connecting the cables to shore under (via micro-tunnels) and/or over (via dredged micro-channels) fringing coral reefs that are up to 2 km across;
- whether and/or how to bury the cables in areas of hard substrate.

Report 2

July, 2010

Introduction

The State of Hawaii's Department of Business, Economic Development, and Tourism (DBEDT) is leading an effort to assess options for the installation of an inter-island undersea power cable between the islands of Molokai, Lanai, Maui, and Oahu. The cable system will provide up to 400 MW of power to the islands of Oahu and Maui from two wind farms that may be developed on the islands of Molokai and Lanai. The University of Hawaii's School of Ocean and Earth Sciences and Technology (SOEST) was contracted to create potential routes for the cables based on existing multibeam sonar data, which were created from a hull mounted system. A key criteria used in proposing routes was DBEDT's desire to bury the cables for as much of their distance as possible. Hull mounted multibeam sonar does provide qualitative data on the hardness of the seafloor, however the pixel resolution at 500-600m depths is generally on the order of 15m, which was adequate for drafting the proposed routes but not for finalizing them. SOEST's recommendations based on the 15m resolution data were submitted to DBEDT in early 2009.

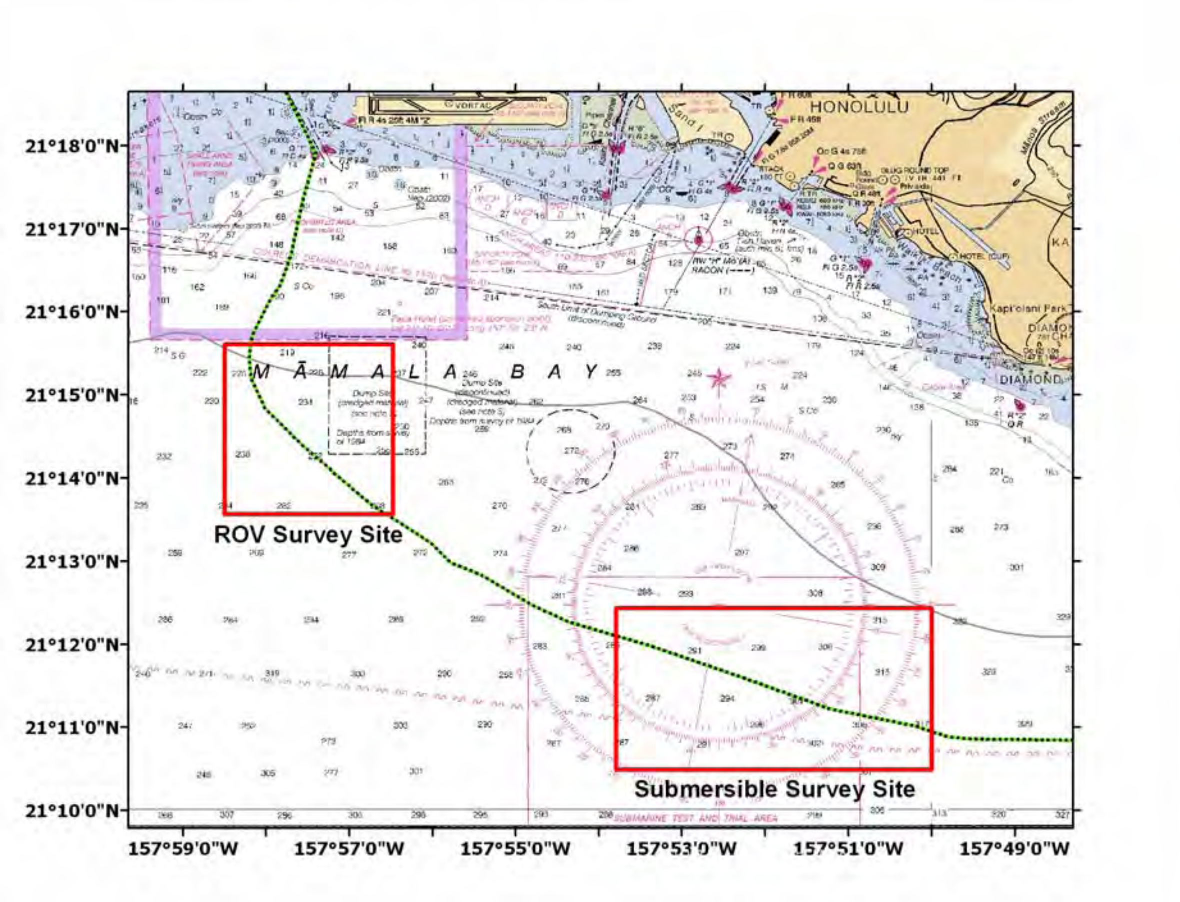
In June and July, 2009, SOEST conducted higher resolution towed multibeam, sidescan sonar, and video camera surveys of the routes that provided the data required for making any necessary adjustments. The University of Hawaii's research ship *R/V Kai'imikai-o-Kanaloa (KOK)* provided the field platform for this work. The sonar data from these surveys were on the order of 1m resolution and were incorporated into a Geographic Information System (GIS). The results from this second project were submitted to DBEDT (Taylor, 2009) along with recommended modifications to avoid obstacles along the routes including hard substrate features and possible manmade metallic objects. Of particular concern was a possibly extensive disposed munitions field along one 4 mile section of the route south of Oahu, further east than known disposal areas. This area had never been surveyed by either submersible or Remotely Operated Vehicle (ROV) and therefore the nature of the objects, which appeared as speckle trails on the sidescan data, were unknown. The towed camera video system used during the surveys has a relatively narrow field of view, however as it passed through this area, it imaged a number of small (i.e. 1 meter long) aerial bombs that appear to match archival photographs of World War I era chemical weapons. At least 16,000 MK47A2 100 lb mustard gas bombs were disposed of south of Oahu in 1945-46, the exact location of which had never been determined (http://www.hummaproject.com/).

The presence of chemical munitions along the route could pose a serious complication during the installation of the cable, and therefore DBEDT contracted SOEST to conduct submersible surveys to identify the objects that appeared on the sidescan sonar and video camera surveys. Prior to the dives, a review of previous submersible and ROV dive tracks also revealed a survey gap of approximately 2.5 miles along the proposed cable route just south the Pearl Harbor Defensive Sea Area (DSA). The area within and south of the DSA was an extensive dredge-spoil and munitions disposal area during and after World War II where a large amount of metal debris has been found. Therefore, an ROV survey of that area was included to obtain a better idea of the number and types of obstacles present in this portion of the route. The submersible and ROV dives were conducted in January, 2010, and this report describes the findings from these surveys.

Methods

Two submersibles, the *Pisces 4* and *Pisces 5* were deployed off the support ship *KOK* to conduct the surveys of the potential chemical munitions area. These vehicles are owned and operated by the Hawaii Undersea Research Laboratory (HURL), which is a federally funded division within SOEST. HURL also owns and operates the RCV-150 ROV which was deployed to survey the second area south of the Pearl Harbor DSA. The dives took place January 25-27, 2010 and the locations of the survey sites are shown in Fig. 1.

Figure 1: Location of the submersible and ROV dive sites (red boxes). The proposed cable route is shown as a green line extending through the sites and into the Pearl Harbor DSA (purple boundary).



Generally HURL only operates one submersible during a typical operation day however the the chief pilot agreed to deploy both subs together on the first and third dive days. This increased the number of submersible dives to 5 and significantly increased the total area surveyed. During the two-sub dives, one sub surveyed directly along the proposed route while the other sub targeted speckle trails either north or south of the route. To ensure accurate tracking and clear communications, the subs generally remained less than a kilometer apart and were deployed near the same start point. Each submersible accommodated the pilot and 2 observers, one of whom was primarily engaged in monitoring the side-looking sonar and directing the pilot to targets of potential interest while the other aided the pilot is visually identifying objects and operating the camera systems. When targets of particular interest were located, the submersible stopped to obtain high definition video, close up still images, and obtain coordinates from the ship's tracking system. The ROV was deployed for a single dive surveying southeast along the cable route from the boundary of the Pearl Harbor DSA. Manmade and natural obstacles were continuously recorded on video during the dive.

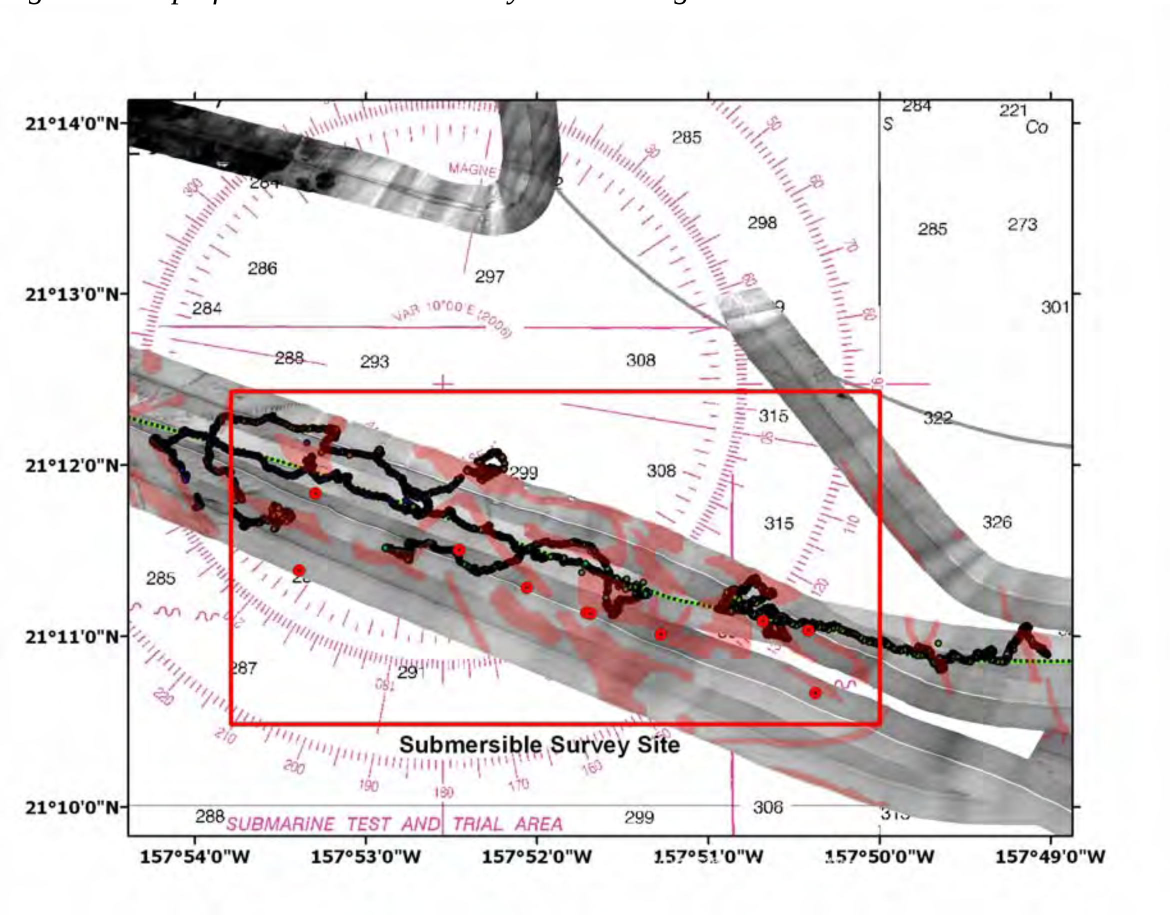
After the cruise was completed, HD and SD video still images were captured of all objects of potential interest, both natural and manmade. A technician was hired to assist with the laser scale measurements of munitions recorded on video for identification purposes and to compare their dimensions to published dimensions of the MK47A2 mustard gas bomb. The technician also cataloged the condition of each bomb, and identified the animals living on or near the bombs. The identification and location of these munitions along with other manmade and natural objects encountered during the dives were then imported into the GIS project for comparison to the sidescan data and the proposed cable route.

Results

Five submersible dives and 1 ROV dive were successfully completed for this project. Fig. 2 provides the submersible dive tracks (lines of dark dots) for the survey of the suspected chemical munitions disposal field. The grey swaths in the image are the sidescan sonar data with the speckle trails highlighted in pink. The locations of the small bombs recorded previously by the towed camera system are shown as red dots. Chemical munitions were documented during the surveys. Because of this, the dives were purposely continued outside of the boundaries of the survey site in an effort to determine the westerly and easterly extents of the field. While various types of munitions were observed in the survey site, two types predominated: small finned aerial bombs consistent in appearance and size with the MK47A2 mustard bomb, and small projectiles that appeared to be either mortar or artillery rounds. Trails within the survey site that could not be investigated during the dives are assumed to consist of one or both of those two types.

A total of 100 small finned bombs were recorded on video during the dives. A few more were also seen by the observers and pilot outside of the video camera field. Example images of these bombs are shown in Fig. 3. The Pisces 4, but not the Pisces 5, was fitted with a 4 point laser scale mounted to the video camera's pan and tilt. This system provided the means to obtain precise measurements of the bombs during dives P4-236, 237, and 238. HURL had only one of these systems available for this project and therefore the dimensions of the bombs recorded on dives P5-742 and 743 could not be as precisely determined. However, the bombs recorded during these dives clearly appeared to be the same type and size as those recorded during the other three dives. Characteristics of the bombs shown in Fig. 3a include the presence of fins and a nose fuse, unlike many larger explosive bombs that were disposed of without either. The fins are "box fins" characteristic of the MK47A2, as are the appearance and location of the two attachment bands. Pressure crushing of the bomb body was also evident, which is not seen with explosive bombs. Chemical bombs were typically manufactured with thinner body walls than explosive bombs, since they were not designed to create shrapnel but rather to break open and disperse their contents (Stauber, pers comm). The observed collapse of the bomb body provides additional evidence of it being chemical in nature.

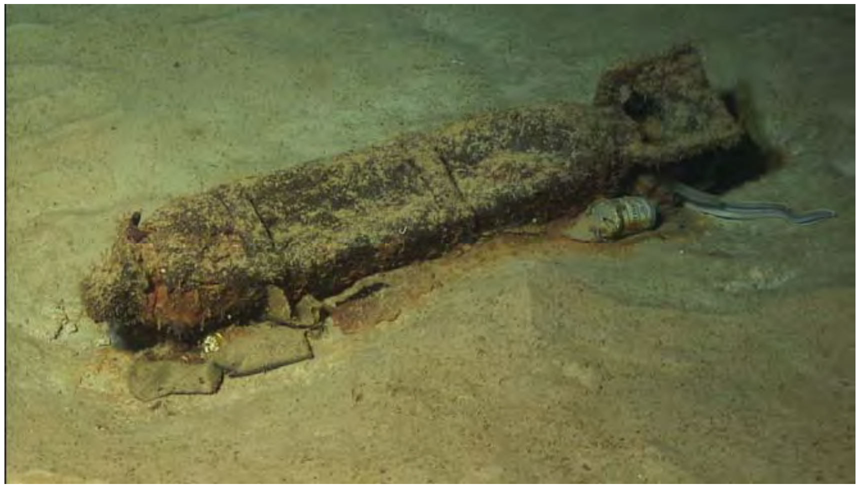
Figure 2: Map of the submersible survey site showing the dive tracks.



Chemical bombs were painted with different colored stripes to facilitate their identification. The color code for mustard gas was typically two green stripes, which the MK47A2s were known to have had. The majority of the bombs found in the survey area were corroded to the point where paint was no longer present or visible. Fig 3b however shows the side of one of three that still had a small amount visible and which clearly shows the two green stripes between the attachment lugs, positively identifying it as an MK47A2.

Most of the bombs showed clear evidence their bodies had been breached, either quickly when the bombs had struck the bottom or slowly over time. The size of the breaches varied considerably from relatively small holes to the point where half of the body was missing. Fig. 3c shows a bomb whose nose has fallen completely off. The red dots are the laser scale being projected from the Pisces 4 submersible. The orange substance at the separation point may be a polymer of the mustard gas agent, which has been documented to form when

Figure 3: Examples of small finned bombs documented during the submersible dives.

a) 

b) 

c) 

German-made mustard gas comes in contact with seawater (Stauber, pers comm). Whether these polymers form when the American formula of mustard gas comes in contact with seawater is presently unknown (Stauber, pers comm).

Fig 4 provides a drawing of the MK47A2 obtained by Steven Price (HURL) from the Internet showing the basic anatomy of the MK47 bomb type. Of particular note are the box fin, protruding nose fuse, and two attachment lugs positioned on the forward half of the bomb body. These lugs have bands than wrap around the bomb body. The bombs shown in Fig. 3 bear a clear resemblance to this type.

Figure 4: Cutaway drawing of an MK47 bomb type (provided by Steven Price, HURL).

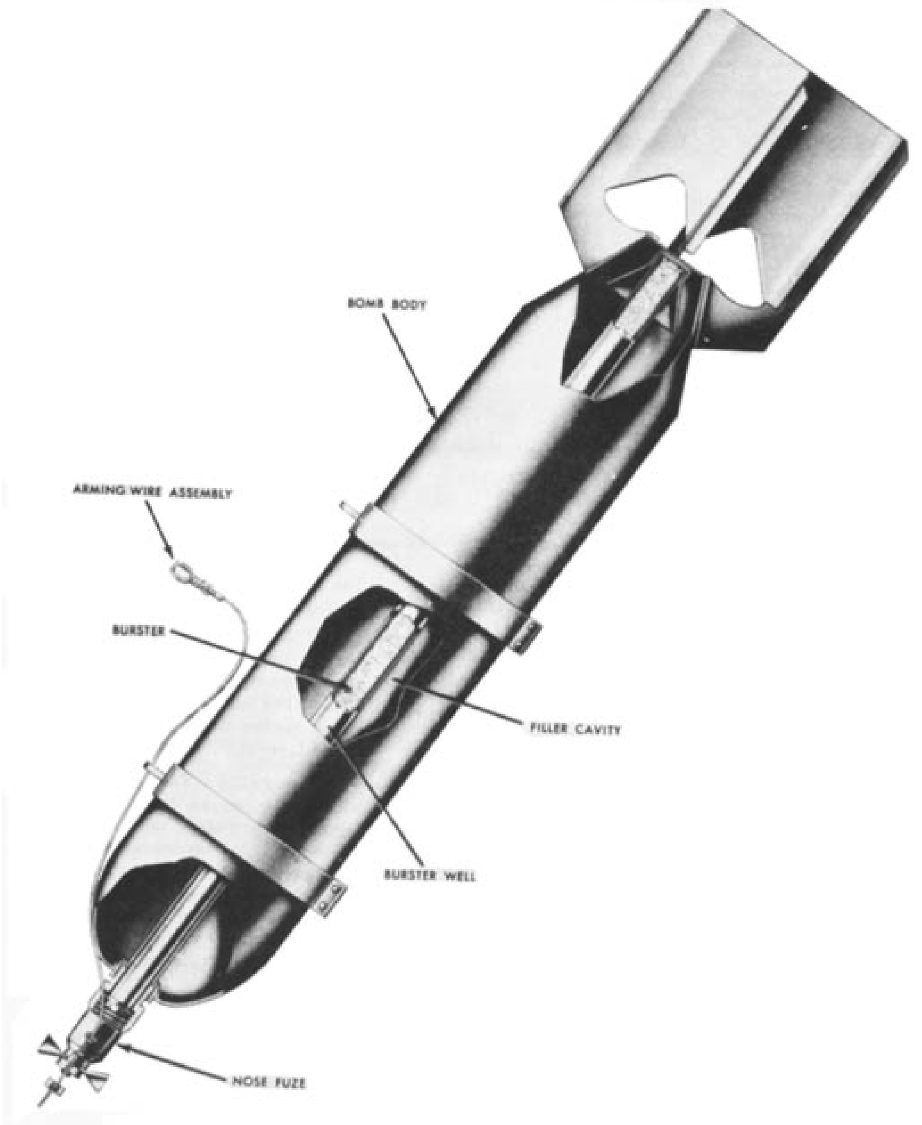


Figure 5 is a diagram obtained from Rick Stauber of Plexus Scientific of the MK47A2 bomb that provides the general shape and dimensions. This diagram has included the two green bands identifying this to be a mustard gas bomb. The diagram shows the bands between the attachment lugs however, the artist was apparently uncertain of their position. Additional information on dimensions was located by Steve Price and is summarized together with those shown below in Table 1.

Figure 5: Diagram of the MK47A2 used in an ordnance identification course by Rick Stauber of Plexus Scientific.

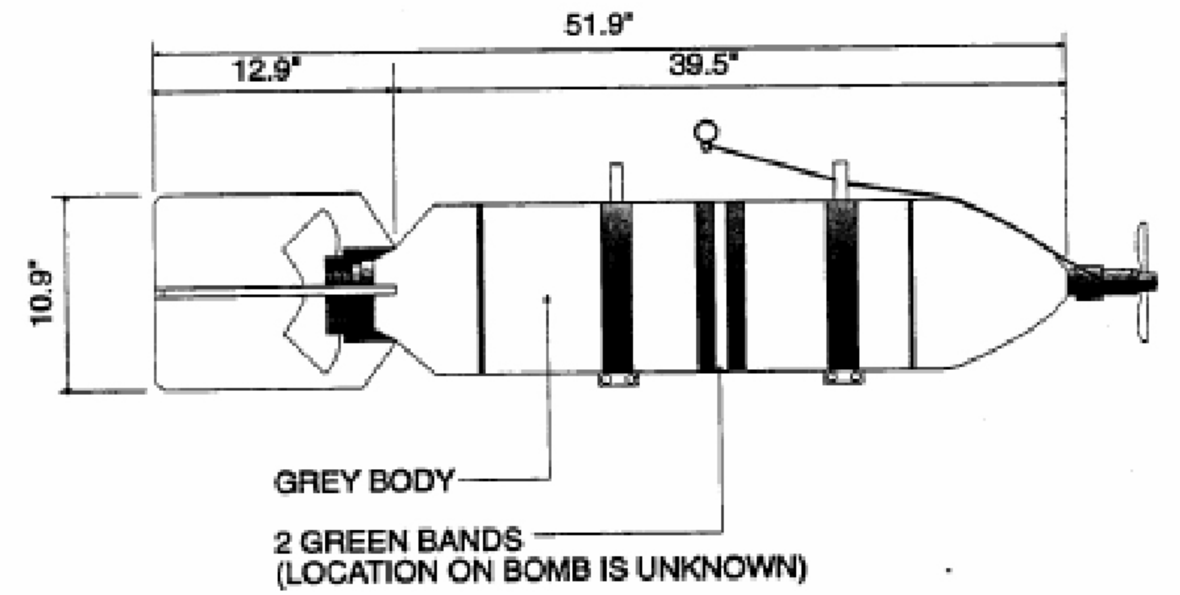


Table 1: Summary of known dimensions of the MK47A2 100 lb chemical bomb

Length (in)	Diameter (in)	Lug Spacing (in)	Fin Length (in)	Fin Width (in)
48.9 - 51.9	8.0	14.0*	12.9	10.9

*Note: attachment lug spacing was obtained for a generalized MK47 bomb type.

With this information for comparison, Table 2 summarizes the dimensions of the bombs found in the submersible survey site determined by analysis of images from the Pisces 4 HD video. Measurements of total length, diameter, attachment lug spacing, fin length, and fin width were extracted where possible. Not all bombs imaged could be reasonably measured and not all measurements could be obtained for each bomb. However, it was possible to obtain measurements for each dimension from between 46-51 bombs. These measurements varied as a result of decreasing accuracy as distance from the submersible increased, as well distortion resulting from the orientation of some bombs to the lasers. Rusticle formation, general corrosion, and pressure crushing had clearly altered the original diameter of the bombs. Given these variances, the average dimensions of the bombs observed during this project were consistent with the known dimensions of the MK47A2.

Table 2: Summary of the bomb dimensions as measured by laser scale.

	Length (in)	Diameter (in)	Lug Spacing (in)	Fin Length (in)	Fin Width (in)
N	46	50	51	51	47
Avg	50.68	8.96	14.14	9.66	9.21
SD	4.07	1.43	2.35	2.40	1.61
Range	43.15-57.96	6.43-13.2	9.58-18.90	4.37-15.0	5.96-12.48

The condition of each bomb was evaluated with respect to its state of corrosion (on a scale of 1-5), integrity or the degree to which the body had been breached (on a scale of 1-5), degree of body collapse due to pressure change on the way to the bottom (on a scale of 1-3), and whether material was visible that could be possible mustard gas agent or its polymer. This was evaluated as being not visible (1), visible inside the bomb as observed through a breach (2), or visible on the seafloor next to the bomb (3). This evaluation was obviously subjective but does serve to provide DBEDT with some idea of their condition. Table 3 provides a summary of this information which was obtained for 96 of the 100 bombs documented.

Table 3: Summary of the condition of 96 of the 100 small finned bombs observed in the submersible survey area.

	Corrosion (1-5)	Integrity (1-5)	Pressure crushing (1-3)	Suspected Material (1-3)
N	96	96	96	96
Avg	4.04	2.32	3.43	1.63
# ranked 1	0	2	4	52
# ranked 2	4	11	57	28
# ranked 3	16	39	35	16
# ranked 4	48	32		
# ranked 5	28	12		

The majority (95%) of the bombs were moderately to extremely corroded, with extensive rusting and rusticles covering their entire surface. The integrity of all but 2 bombs had clearly been compromised and ranged between relatively small holes in the body, collapsed nose sections, or half of the bomb entirely missing. All but 4 of the bombs showed clear signs of pressure crushing, with the exceptions all having holes that may have been present or formed on descent. Pressure crushing can be taken as an indicator of whether the bomb was intact and not leaking when disposed. This likely occurred as a result of a small air space remaining in the bomb body after it had been filled with its contents. If the bomb was leaking, the opening in the body wall would have provided the means by which this air could have escaped. In over half of the bombs, material that was possibly mustard gas agent was not visible either inside or leaking outside of the body. Material inside or next to the other bombs still needs to be identified since it could be mustard agent, iron oxide, some combination of both, or something else entirely.

Table 4 provides a list of the animals observed on and around the bombs. These include 14 types of cnidarians, 2 sponges, 1 worm, 10 echinoderms, 7 crustaceans, 1 mollusk, and 14 species of fishes. Those animals observed actually perched on the bombs are typically observed elsewhere on hard substrate. Most of the natural substrate in the bomb field was flat sediment and for these animals, the bombs provide the only source of shelter for fishes and crabs, attachment surfaces for cnidarians and sponges, and perches off the bottom for seastars and crinoids. The bombs are therefore serving as artificial reefs at the micro-habitat scale and most of these animals would likely not be present or would be in much less abundance if the bombs were not there. With the exception of 2 pandalid shrimps: *Heterocarpus ensifer*, and *Heterocarpus laevigatus*, none of the animals were of commercial value. These two shrimps, however, are the target of deepwater shrimp fisheries elsewhere in the main islands, particularly off Niihau. Furthermore, these and other shrimp are consumed by commercially harvested bottomfish, as are the congrid eels. Follow up studies should include testing the tissue of these animals for the presence of mustard gas agent.

Table 5 provides observations of these animals relative to the presence of suspected mustard agent material. The animals are listed in the order of the total number of bombs they were observed on or near. This number is then broken down to a) bombs where no material that could be mustard agent was visible, b) bombs where the material was only observed inside the body, and c) bombs where material was observed outside the body on the seafloor. The total number of animals found on the bombs was also obtained. In general, animals colonized a larger proportion of bombs with no material visible from the video. For example, hormathiid anemones (Fig. 6) were present on 65 of the 100 bombs, 34 of which did not show any material in the images. A total of 444 animals were counted on "no material" bombs with no material visible versus 335 on bombs with material visible on the inside and 112 on bombs with material on the outside. Cnidarians, particularly hydrozoans, hormathiid anemones, and zoanthinarians, along with shrimp were the most abundant animals observed. When interpreting these findings, however, it is important to remember that this material in and around the bombs has not been confirmed to be chemical in nature. The lower number of animals on bombs where material was present could also be a response to a higher degree of corrosion which would therefore provide a less stable and attractive attachment surface. For the moment, these data only suggest that additional work currently being considered by the Army to acquire a larger sample set would indeed be worthwhile.

The location of each of the bombs was determined by correlating the video and tracking data time stamps. Submersible and tracking room electronic clocks are synchronized as part of the daily pre-dive preparations. Video time is recorded continuously while tracking data time is recorded on 10 second intervals. The closest track points for all 100 bombs recorded on video were obtained from the tracking data and imported into an ArcGIS as a shapefile. Figure 7 provides a map showing their locations along with the locations of the bombs recorded previously by the towed camera system. No small finned bombs similar in appearance to MK47A2s were found outside of the 4 mile wide survey site. However conventional ordnance was observed both east and west of the site that included ammo boxes filled with 50 cal rounds, hedgehogs (contact depth charges), a torpedo, parachute bombs, possible Bangalore torpedos, incendiary bombs, piles of discarded fuses, and mortar shells. Small finned bombs were found throughout the survey site, many of which were directly on the route.

Table 4: List of animals observed on or near the small finned bombs.

Group	Category	Subcategory	Identification
Cnidarians	Anemones	Hormathiidae	Hormathiidae
	Anemones	Actinernidae	Actinernus sp
	Tube Anemones	Cerianthidae	Cerianthidae
	Hydrozoans	Tubulariidae	Tubulariidae sp1
	Hydrozoans	Tubulariidae	Tubulariidae sp2
	Hydrozoans	Hydrozoan	Hydrozoan
	Sea Pens	Kophobelemnidae	Kophobelemnon steliferum
	Sea Pens	Virgulariidae	Virgulariidae
	Sea Pens	Pennatulidae	Pennatulidae
	Gorgonians	Corallidae	Corallium niveum
	Gorgonians	Isididae	Isididae
	Gorgonians	Isididae	Keratoisis flabellum
	Zoanthinarians	Zoanthinarian	Zoanthinarian
	Cnidarians	Cnidarian	Cnidarian Orange
Sponges	Hexactinellids	Euplectellidae	Regadrella1
	Hexactinellids	Euplectellidae	Regadrella2
Worms	tubeworm	tubeworm	tubeworm tube
Echinoderms	Urchins	Aspidodiadematidae	Aspidodiadema hawaiiensis
	Urchins	Cidaridae	Histocidaris variabilis
	Urchins	Cidaridae	Stereocidaris hawaiiensis
	Urchins	Pedinidae	Caenopedina hawaiiensis
	Urchins	Echinothuridae	Phormosoma bursarium
	Seastars	Brisingidae	Brisinga alberti
	Seastars	Brisingidae	Brisinga panopla
	Seastars	Echinasteridae	Henricia pauperrima
	Sea Lilies	Comatulinae	Comatulinae tan
	Sea cucumbers	Deimatidae	Orphnurgus sp
Crustaceans	Barnacles	Scalpellidae	Scalpellidae
	Crab	Majidae	Cyrtomaia smithi
	Shrimp	Pandalidae	Heterocarpus ensifer
	Shrimp	Pandalidae	Heterocarpus laevigatus
	Shrimp	Shrimp	Shrimp
	Shrimp	Aristeidae	Benthesicymus laciniatus
	Shrimp	Pandalidae	Plesionika alcocki
Mollusks	Cephalopods	Octopodidae	Octopus
Fishes	Sharks	Hexanchidae	Hexanchus griseus
	Sharks	Squalidae	Squalus mitsukurii
	Rays	Plesiobatidae	Plesiobatis daviesi
	Rays	Hexatrygonidae	Hexatrygon bickelli
	Eels	Congridae	Congrid black
	Eels	Congridae	Congrid white
	Benthic	Acropomatidae	Synagrops sp
	Benthic	Lophiidae	Lophiidae
	Benthic	Macrouridae	Ventrifossa atherodon
	Benthic	Macrouridae	Lucigadus sp
	Benthic	Macrouridae	Malacocephalus boretzi
	Benthic	Macrouridae	Hymenocephalus antraeus
	Benthic	Scorpaenidae	Setarches guentheri
	Benthic	Scorpaenidae	Scorpaenidae

Table 5: Summary of animals observed on or near the small finned bombs relative to the presence of material either inside or outside of the bomb bodies that could be mustard agent.

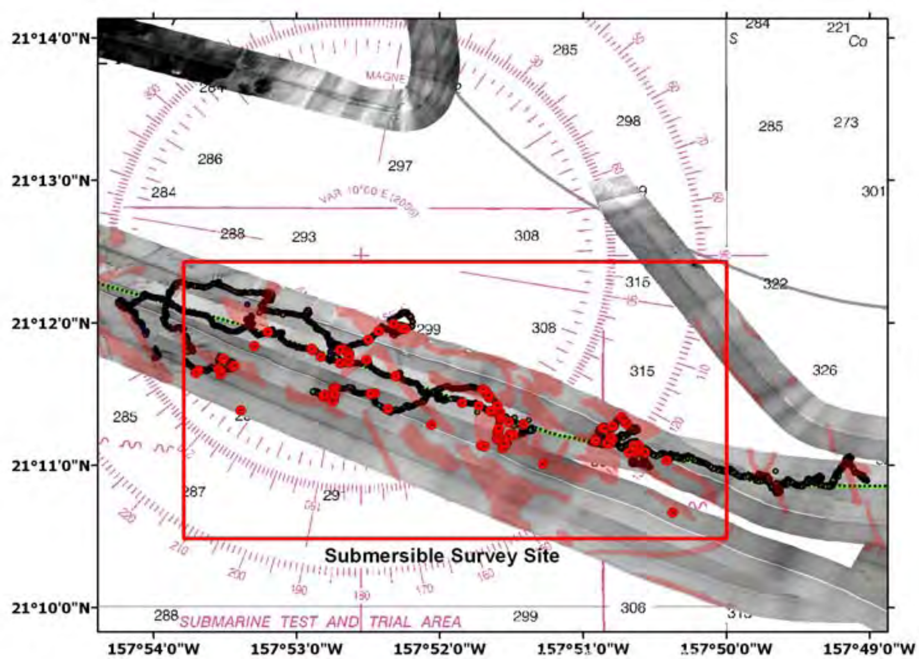
Category	Subcategory	Identification	Total Bombs	Bombs w/No Mat	Bombs w/Mat Inside	Bombs w/Mat Outside
Anemones	Hormathiidae	Hormathiidae	**65**	34	20	11
Shrimp	Shrimp	Shrimp	**32**	17	9	6
Shrimp	Pandalidae	Heterocarpus laevigatus	**25**	15	7	3
Hydrozoans	Tubulariidae	Tubulariidae sp1	**17**	7	8	2
tubeworm	tubeworm	tubeworm tube	**17**	8	7	2
Urchins	Aspidodiadematidae	Aspidodiadema hawaiiensis	**15**	6	8	1
Benthic	Acropomatidae	Synagrops sp	**15**	9	3	3
Sea Pens	Kophobelemnidae	Kophobelemnon steliferum	**13**	7	2	4
Hexactinellids	Euplectellidae	Regadrella1	**12**	7	5	0
Benthic	Macrouridae	Hymenocephalus antraeus	**11**	5	5	1
Seastars	Brisingidae	Brisinga panopla	**10**	7	2	1
Sea Pens	Virgulariidae	Virgulariidae	**9**	6	1	2
Urchins	Echinothuridae	Phormosoma bursarium	**9**	4	3	2
Eels	Congridae	Congrid white	**9**	6	2	1
Hydrozoans	Hydrozoan	Hydrozoan	**8**	4	4	0
Benthic	Scorpaenidae	Setarches guentheri	**8**	3	4	1
Zoanthinarians	Zoanthinarian	Zoanthinarian	**7**	2	3	2
Gorgonians	Isididae	Isididae	**6**	3	2	1
Benthic	Macrouridae	Malacocephalus boretzi	**6**	4	2	0
Barnacles	Scalpellidae	Scalpellidae	**5**	2	1	2
Urchins	Cidaridae	Histocidaris variabilis	**5**	3	2	0
Urchins	Cidaridae	Stereocidaris hawaiiensis	**5**	3	1	1
Cnidarians	Cnidarian	Cnidarian Orange	**4**	2	1	1
Crab	Majidae	Cyrtomaia smithi	**4**	2	2	0
Shrimp	Aristeidae	Benthesicymus laciniatus	**4**	3	1	0
Sea Lilies	Comatulinae	Comatulinae tan	**4**	1	0	3
Benthic	Macrouridae	Ventrifossa atherodon	**4**	2	0	2
Gorgonians	Isididae	Keratoisis flabellum	**3**	1	1	1
Hydrozoans	Tubulariidae	Tubulariidae sp2	**3**	1	1	1
Hexactinellids	Euplectellidae	Regadrella2	**3**	2	1	0
Anemones	Actinernidae	Actinernus sp	**2**	1	1	0
Sea Pens	Pennatulidae	Pennatulidae	**2**	2	0	0
Shrimp	Pandalidae	Heterocarpus ensifer	**2**	0	2	0
Seastars	Brisingidae	Brisinga alberti	**2**	0	1	1
Seastars	Echinasteridae	Henricia pauperrima	**2**	1	0	1
Rays	Plesiobatidae	Plesiobatis daviesi	**2**	1	0	1
Sharks	Squalidae	Squalus mitsukurii	**2**	2	0	0
Gorgonians	Corallidae	Corallium niveum	**1**	1	0	0
Tube Anemones	Cerianthidae	Cerianthidae	**1**	1	0	0
Shrimp	Pandalidae	Plesionika alcocki	**1**	0	0	1
Sea cucumbers	Deimatidae	Orphnurgus sp	**1**	0	1	0
Urchins	Pedinidae	Caenopedina hawaiiensis	**1**	1	0	0
Benthic	Lophiidae	Lophiidae	**1**	0	1	0
Benthic	Macrouridae	Lucigadus sp	**1**	0	1	0
Benthic	Scorpaenidae	Scorpaenidae	**1**	0	1	0
Eels	Congridae	Congrid black	**1**	1	0	0
Rays	Hexatrygonidae	Hexatrygon bickelli	**1**	1	0	0
Sharks	Hexanchidae	Hexanchus griseus	**1**	0	1	0
Cephalopods	Octopodidae	Octopus	**1**	1	0	0

The positions of the bombs roughly coincided with the positions of speckle trails (pink areas) from the 2009 sidescan sonar survey, with differences assumed to be due to positioning error from both the sonar and submersible tracking systems. Based on these trails and other trails that were not investigated during the survey, it is estimated that more than 1,000 of these bombs may be present within the 4 mile long by 1 mile wide swath that was mapped in this portion of the cable route.

Other potential obstacles to the installation of the cable were recorded during the dives and included several large house-sized carbonate boulders, old disposed cars, a small airplane that had crashed in the 1990s, old 55 gal drums, and various types of small metal and other manmade objects.

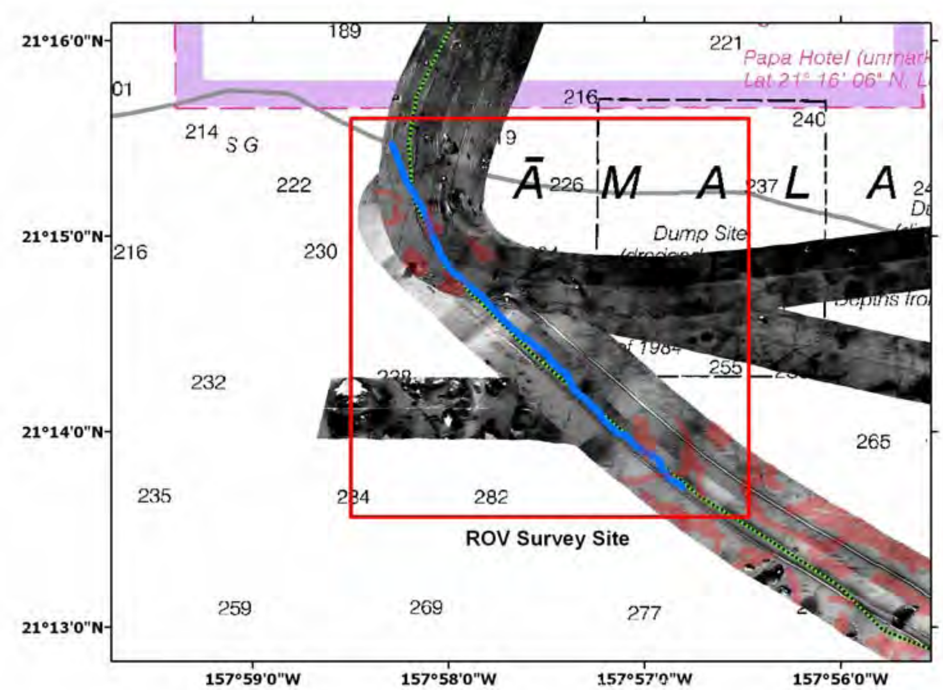
Figure 6: Hormathiid anemones (right) and a Regadrella sp. 1 sponge (white center) attached to a small finned bomb.

Figure 7: Map of the submersible dive site showing the locations (red dots) of small finned bombs resembling MK47A2s.



The ROV was used to survey a 2.5 mile survey of the cable route immediately south of the Pearl Harbor DSA boundary (Fig. 9). The purpose of the dive was to determine whether munitions or other obstructions were present. No chemical munitions were seen during the survey, however conventional munitions were documented on video and included naval rounds, 50 cal ammo boxes, gun round stacks, large explosive bombs (500 lb?) with retaining rings but no fins, and a depth charge. Other debris included airplane parts (a wing root section), barbed wire bundles, a liquid tank, a propeller blade, tires, canvas, hoses and many unidentified metal objects. The substrate throughout this section of the cable route was generally flat sediment with occasional small sand waves.

Figure 9: Map showing the ROV dive track through the survey site south of Pearl Harbor.



Discussion

The submersible and ROV dives were successfully completed for this project and documented the obstacles present in the two targeted survey sites along the proposed interisland cable route south of Honolulu. The 5 submersible dives confirmed the presence of small finned bombs in a 4 mile long stretch of the route that appear to match archival drawings of MK47A2 100 lb mustard gas bombs known to have been dumped by the army in 1945-46. Other obstacles to the installation of the cable were observed in both the submersible and ROV survey areas. These potential MK47A2s are of the most concern, however, since it's doubtful they can be cleared from the path in a safe and economically feasible manner. Based on sidescan sonar images of the survey area, the 100 bombs that were documented during the dives appear to represent only a fraction of the bombs along that portion of the route. These bombs were found to be significantly corroded, many had visible breaches to their bodies and would probably break up if a rake or trawl was used in an attempt to remove them. If these do indeed contain mustard gas, this agent is oily and would likely contaminate whatever gear it came in contact with, which could pose a significant risk to the gear handlers back on deck. In June, 2010, a clam fisherman was burned on both his arms and legs after handling several mustard gas canisters that were inadvertently brought on board his boat. Details of this incident can be found at: (http://www.boston.com/news/local/breaking_news/2010/06/signs_of_bliste.html).

At the present time, we feel the best course of action is for the Army to conduct additional surveys of the area that includes sampling to confirm the presence of mustard gas agent, determine whether it may be having an effect on the benthic fish and invertebrate community in the area, and to determine the full extent of the disposal field. We do not recommend the State or the Army attempt to remove these objects, and recommend instead that they be left in place to corrode naturally. We further recommend that if the bombs are confirmed to contain mustard gas, the area be officially designated as an ordnance disposal area where trawling, anchoring, or any other type of activity requiring bottom contact be prohibited.

With regard to the inter-island cable, it seems the most reasonable approach is for the state to find an alternate route around the field or to abandon their plans to install a south shore landing. DBEDT already contracted SOEST to conduct additional sidescan sonar surveys north of the present cable route to determine if an alternate can be found. This work was completed in March, 2010 and the findings will be provided shortly in a separate report.

Citations

Taylor, B. 2009. Hawaii inter-island cable project ocean floor survey task 2d technical final report. Report submitted to DBEDT November, 2009.

Appendix 1: Project Participants

The following is a list of the participants in the submersible and ROV dives that were conducted for this project:

Christopher Kelley, HURL, Chief Scientist and Submersible Observer
Terry Kerby, Pisces Chief Pilot
Dan Greeson, ROV Chief Pilot
Max Cremer, Pisces Pilot
Pete Townsend, ROV Pilot
Submersible Observers:
Margo Edwards, SOEST
Allen Kam, DBEDT
Kathryn MacDonald, SOEST
Rachel Orange, HURL
Steve Price, HURL
Alexander Shor, SOEST

Report 3

August, 2010

Technical Final Report

Contract Number 59110

“Ocean Floor Survey Extension #2”

From

State of Hawaii

Department of Business, Economic Development and Tourism

To

University of Hawaii

Brian Taylor, Principal Investigator

Submitted August 24, 2010

In fulfillment of Contract Task 1b

Executive Summary

New deep-towed sidescan sonar maps are provided of previously recommended and alternate potential routes for ocean floor power cables between Oahu and Molokai/Lanai. These data extend the likely region of dumped chemical munitions south of Oahu such that, together with other obstructions in the area (dumped ordnance, machinery and debris, planned cold water intake pipe) we can no longer identify a route to lay a power cable south of Oahu to Pearl Harbor/Honolulu that does not contain some physical or chemical hazard. The data do confirm and better characterize several recommended options for cable routes between Kaneohe and NW Molokai and Lanai that minimize but can not eliminate route segments that cross deep reef rock in the Ka’iwi Channel.

Introduction

This is the third of three technical reports submitted by the University of Hawaii's School of Ocean and Earth Sciences and Technology (SOEST) to the State of Hawaii's Department of Business, Economic Development, and Tourism (DBEDT) on the findings of 3 contracted surveys along various potential routes for undersea power cables between the islands of Molokai, Lanai, Maui, and Oahu. As part of the first survey, high-resolution deep-towed multibeam and sidescan sonar data as well as video camera footage was obtained along most of a proposed route system in June and July, 2009. The multibeam and sidescan sonar data were collected from the University of Hawaii's research ship R/V *Ka'imikai-o-Kanaloa* (KOK) using the Naval Research Laboratory's (NRL) deep towed sonar system DT-1. Both types of data have resolution on the order of 1m and were incorporated into a Geographic Information System (GIS). Then, using the same ship, video camera footage was collected using a custom built deep-towed camera system. The findings from the first survey were submitted in the first technical report to DBEDT (Taylor, 2009) and recommended modifications to potential routes previously identified in a desk-top study to avoid obstacles including hard substrate features and possible manmade metallic objects. Of particular concern was a possibly extensive disposed munitions field along one 4 mile section of a route south of Oahu, further east than known disposal areas. The sidescan sonar data showed an extensive pattern of "speckle trails", which elsewhere have been confirmed by submersible to be disposed munitions (see http://hummaproject.com/team.php). As the towed camera passed through these trails, it recorded a number of small (i.e. 1 meter long) aerial bombs that appear to match archival photographs of World War I era chemical weapons. At least 16,000 MK47A2 100 lb mustard agent bombs were disposed south of Oahu in 1945-46, the exact location of which had never been determined.

The possible presence of chemical munitions along cable routes leading into Pearl Harbor would pose serious complications for cable installation and maintenance, and therefore DBEDT contracted SOEST to conduct a second survey to identify the objects that appeared on the towed video camera footage. This survey was conducted January 25-27, 2010 using the Pisces IV and V submersibles along with the RCV-150 Remotely Operated Vehicle (ROV) operated by the Hawaii Undersea Research Laboratory (HURL). Over 100 bombs were documented that were tentatively identified as MK47A2s based on their size, shape, and the presence of green paint bands on several that confirmed they contained chemical agent. The findings, provided last month in a second technical report to DBEDT (Taylor, 2010), indicated the need to detour the potential route around the chemical bomb field. However, the extent of the field along the north-south axis was unknown.

In February, 2010, DBEDT was informed that NRL's DT-1 towed sonar system was returning to the islands for a Navy-funded survey off Barber's Point, Oahu and that they could "piggyback" a few additional mapping days onto that project, saving the considerable costs associated with mobilizing the equipment and staff from the east coast. Therefore, DBEDT contracted SOEST to conduct a third survey aimed at obtaining sidescan sonar data north of the bomb field. While specific types of munitions can not be identified from sidescan data, speckle trails would indicate the presence of disposed munitions of some kind that a detour of the original route should avoid.

In addition to mapping this area, the NRL's towed sonar system was used to conduct additional mapping further to the east on primary and alternate potential routes between east Oahu and

Molokai/Lanai. The recommended potential routes to date have included some segments without full deep-towed sonar coverage after the originally proposed routes were modified in light of the results of the first surveys in 2009. Mapping these segments was and will be useful in evaluating their suitability, and for the Environmental Impact Assessment (EIA). This third technical report to DBEDT summarizes the findings from this third and latest survey.

Methods

Similar to the first survey, NRL's towed sonar system was deployed from the ship KOK (Fig 1). A winch and data control center was set up in the KOK dry lab that was manned around the clock by NRL and University of Hawaii staff (Fig 2).

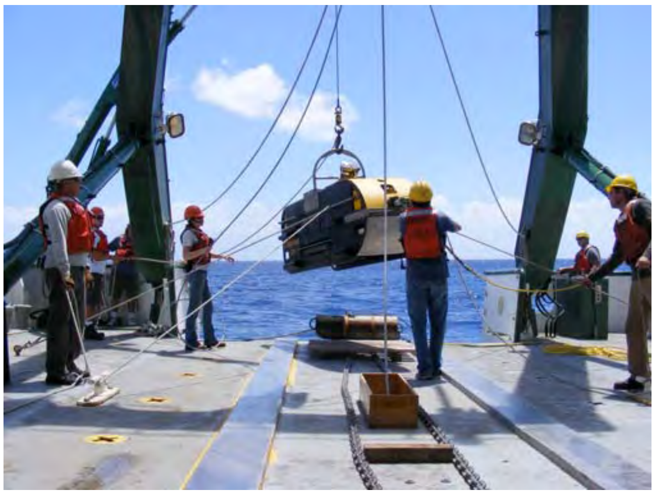


Fig 1: NRL's DT-1 towed sonar system being deployed from the back deck of the RV KOK.

Fig 2: Winch and data control center set up in the KOK's dry lab.

The cruise took place March 26-27, 2010 following 2 days of mapping for the Navy off Barber's Point, Oahu. The two mapping objectives are shown in Fig 3, the first being a set of 8 lines in an area immediately north of the bomb field along the potential route to/from Pearl Harbor and the second being segments along potential routes between east Oahu and Molokai/Lanai.

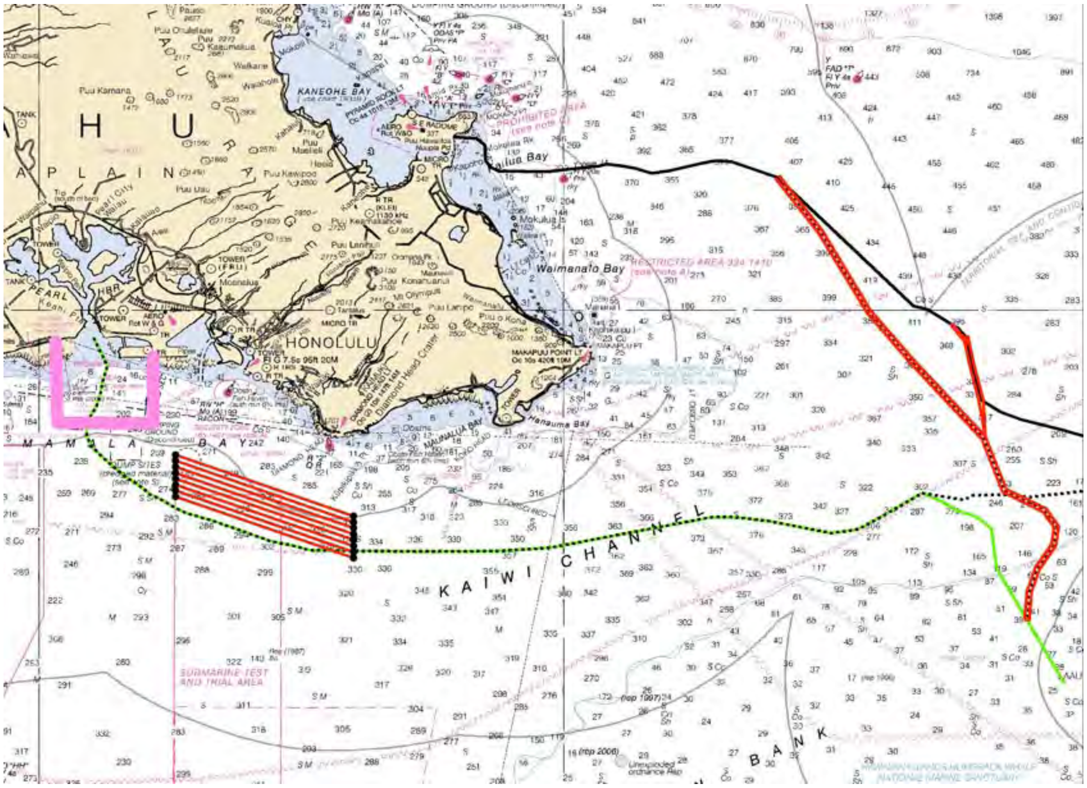


Fig. 3: Tracklines (red) for the two mapping objectives 1) the area north of the potential route leading into Pearl Harbor, along which possible chemical munitions had been found, and 2) segments along the potential routes between Oahu and Moloka/Lanai.

Figure 4 provides the actual ship track lines showing that both objectives were met. Within a relatively tight schedule of only 48 hrs, all of the mapping lines were completed as well as approximately 30% of an extra 9th line north of the bomb field.

Following the cruise, the sidescan sonar data were processed into 24 bit Geo-TIFFs by Paul Johnson of the Hawaii Mapping Research Group. Unlike typical geo-referenced images, these contained the full range of intensities for the sidescan sonar data allowing greater control of contrast and brightness for visualizing the speckle trails. The Geo-TIFFs were added to the existing Interisland Cable GIS project for analysis. For the first objective, this involved identifying all speckle trails in the new data, creating polygons around these trails for greater visibility, and finding the best possible detour north of the original route to get around or through the field. For the second objective, the proposed alterations to the routes between Oahu and Molokai/Lanai were evaluated with respect to these new data. Of particular importance was the identification of optimal routes over two drowned reef terraces, one extending seaward of Makapuu Pt, Oahu and the other paralleling the west coast of Molokai. For the latter, two routes through the Molokai deep water terrace were to be identified, one taking a branch of the cable to Ilio Point (or thence to Lauu Pt) and the other taking the cable around the southwest of Molokai to Lanai.

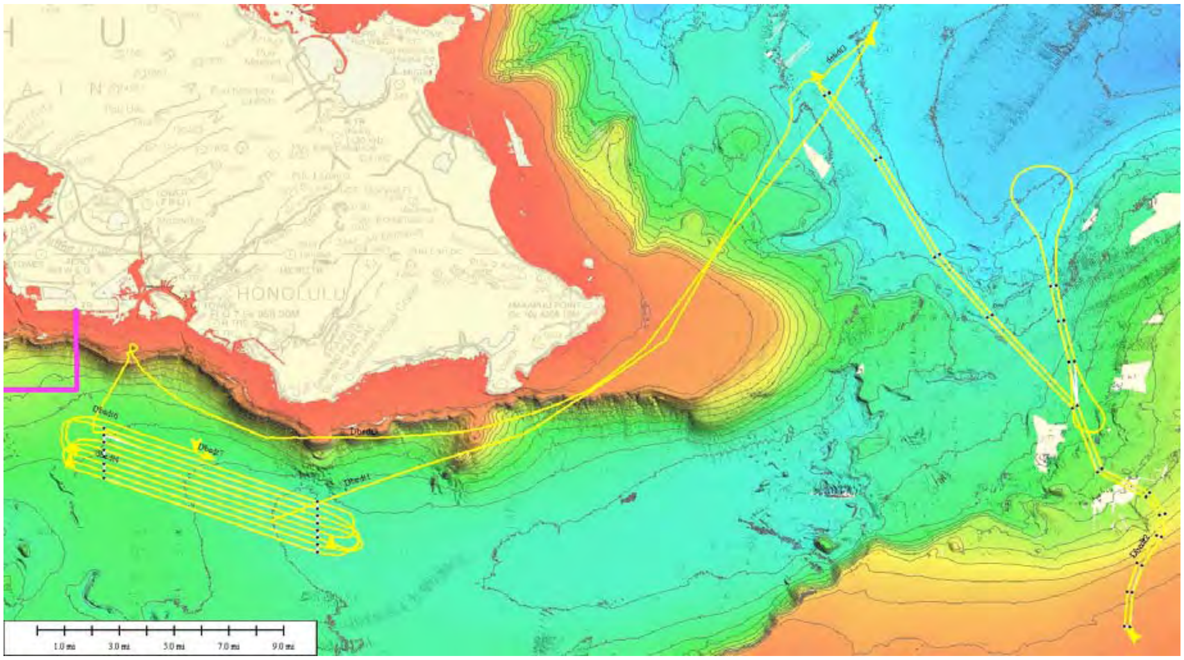


Figure 4: Image of the survey areas created with Global Mapper software showing the actual KOK ship tracks from the cruise.

Additional archival data were acquired and included with the new DT-1 sidescan data for these analyses. For objective 1 south of Honolulu, sidescan data collected by Fugro International's Autonomous Underwater Vehicle (AUV) for a privately funded study were examined, since it overlapped with the most northerly tracks of the present study. Polygons were created around speckle trails from that survey which were incorporated into the GIS. In addition, the general position of a proposed cold seawater intake pipe extending south of Honolulu Harbor was included in the analysis since it constitutes a potential barrier for the cable routes. The positions of conventional munitions identified for the Hawaii Undersea Military Munitions Assessment (HUMMA) project and wreckage identified by HURL over the years such as boats, planes, and disposed vehicles were added. The munitions include projectiles, depth charges, and bombs that are non-chemical in nature but, along with the wreckage, are still considered obstacles to the installation of a power cable. For objective 2, additional swaths of R/V Kilo Moana multibeam backscatter data between Oahu and Molokai were processed and included in the GIS that more clearly showed the extent and character of the terraces.

Results

Objective 1: Sidescan sonar mapping of the bomb field south of Honolulu

The mapping of all 8 tracklines was completed as planned with enough time to add 30% of an additional 9th line. Figure 5 shows a mosaic of the data obtained for this objective.

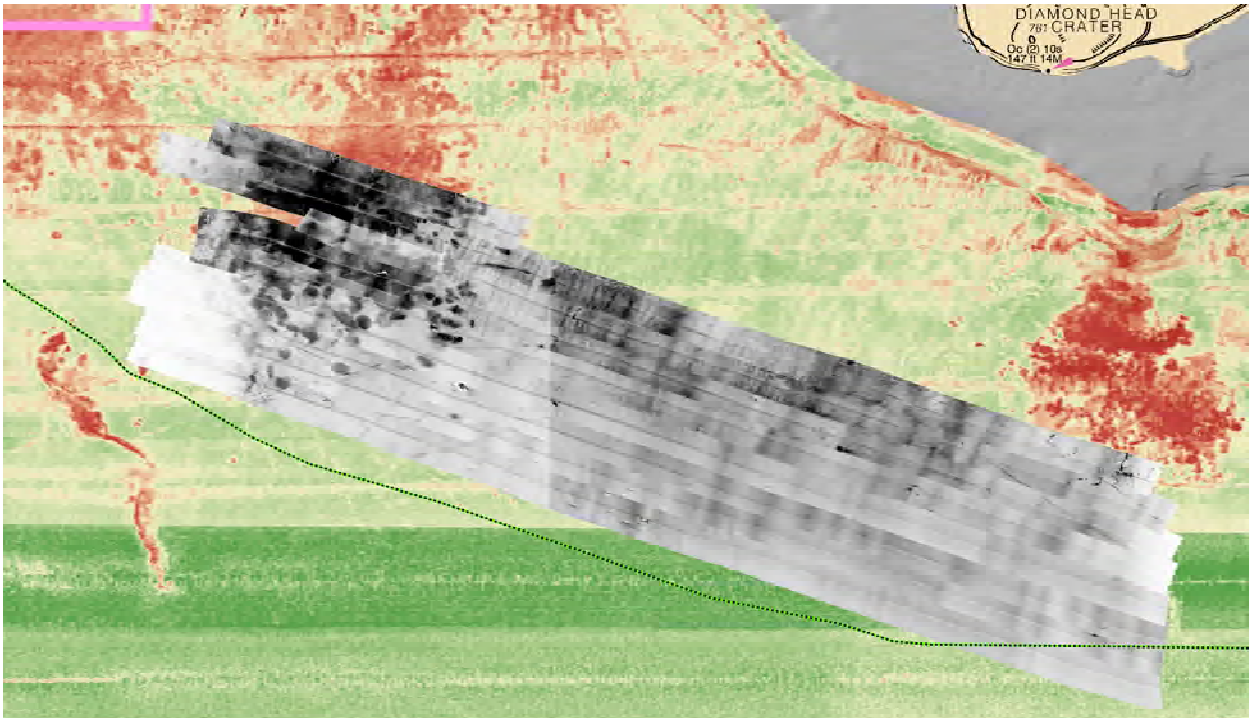


Figure 5: Mosaic of the DT-1 sidescan sonar data obtained for objective 1 south of Honolulu.

The original potential cable route is the green dotted line displayed over multibeam backscatter data, where red is hard and green is soft substrate. The new sidescan data mosaic is shown with a white to black ‘color’ bar, where darker is more reflective or hard substrate and lighter is non-reflective soft substrate. These data were processed at 1 meter resolution and close-up inspection revealed a considerable number of speckle trails throughout the 8 tracks that are almost certain to be disposed munitions (Fig 6). The top image in Fig 6 shows trails found in the northwest end of the survey area that corresponded to various types of conventional explosive munitions previously documented during submersible dives conducted for the HUMMA project in 2008. Known types disposed in this area include depth charges, large (i.e., 500 lb) bombs, incendiary bombs, crates of mortar and 155 mm naval rounds, bundles of elongated cylinders believed to be Bangalore torpedos, and boxes of 50 caliber machine gun rounds.

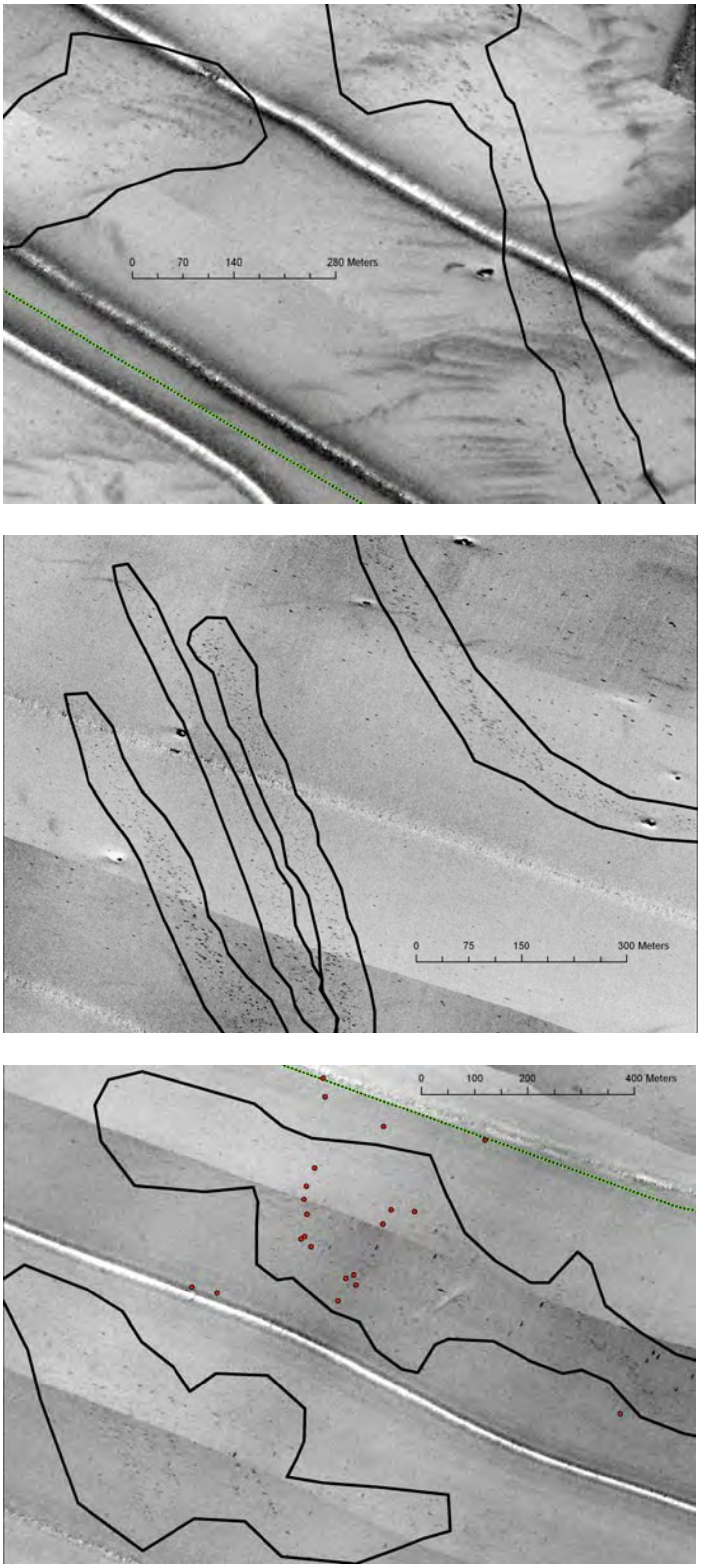


Fig 6: Examples of speckles trails/fields (outlined with black lines) from the DT-1 sidescan sonar data that correspond to confirmed conventional munitions of various sizes (top), suspected small conventional munitions (middle), and confirmed chemical munitions (bottom).

The middle image shows dense trails of relatively small munitions that are probably conventional. The bottom image shows relatively scattered fields of confirmed (i.e., red dots) MK47A2-type small finned bombs that were documented during the second submersible survey conducted for DBEDT. In general, dense trails are believed to be smaller lighter munitions such as ammo boxes and individual mortar rounds that were easier and faster to throw over the side than larger, heavier munitions such as 500 lb bombs and depth charges. The latter types were likely rolled on the deck by a single sailor and pushed individually out an opening in the side of the barge. MK47A2 100 lb bombs, while being smaller, were individually crated and had attached fins so they couldn’t be rolled. Each undoubtedly required 2 persons, one on each end, to carry and throw over the side. These bombs, which would have taken more time to unload from the barges, are most likely associated with lower density trails and fields except where multiple disposal events took place at the same spot.

Figure 7 provides a summary image of all suspected and known obstacles to the installation of a power cable south of Oahu. These include suspected (black polygons) and known (small black dots) convention munitions, wreckage (larger black dots), suspected (yellow polygons) and known (red dots) chemical munitions, the planned cold seawater pipe (thick black line) and dredge spoil (red areas of background acoustic imagery). The green dotted line is the previously proposed potential cable route. It is clear from the image that while such a route would take the cable around much of the dredge spoil deposits from Pearl and Honolulu Harbors, it also takes it directly through a considerable region of newly discovered disposed munitions including suspected MK47A2 mustard agent bombs. Either chemical or conventional munitions, wreckage, or dredge spoil are present along most of the route from Diamond Head to the entrance of Pearl Harbor. On that basis, we consider this potential power cable route south of Oahu to be problematic and no longer recommend it.

The new sidescan mapping data from this survey did not reveal an acceptable detour to the north and instead revealed substantial suspected munitions trails and fields all the way up past the intake of the proposed cold seawater air conditioning pipe. The pipe itself poses a significant obstacle to the installation of the cable since it will run from shore to a depth of 544m and will be supported 5 ft off the bottom by concrete blocks. Once the pipe is installed, anticipated in late 2011, it will not be possible to lay the cable across that area.

We were furthermore unable to identify an acceptable southern detour, due both to a lack of data as well as the presence of munitions, dredge spoil, and old reef outcrops as the route turns north toward the Pearl Harbor Defensive Sea Area. No deep towed sidescan sonar mapping has been conducted south of the MK47A2 bomb field and therefore the presence of additional chemical munitions in that area is unknown, though highly likely. Additional mapping would need to be conducted if DBEDT wishes to pursue a southern detour around the known bomb field. Even if such was found, portions of the route would still cross substantial dredge spoil deposits and dumped materials that likely would need to be cleared of obstacles prior to cable installation.

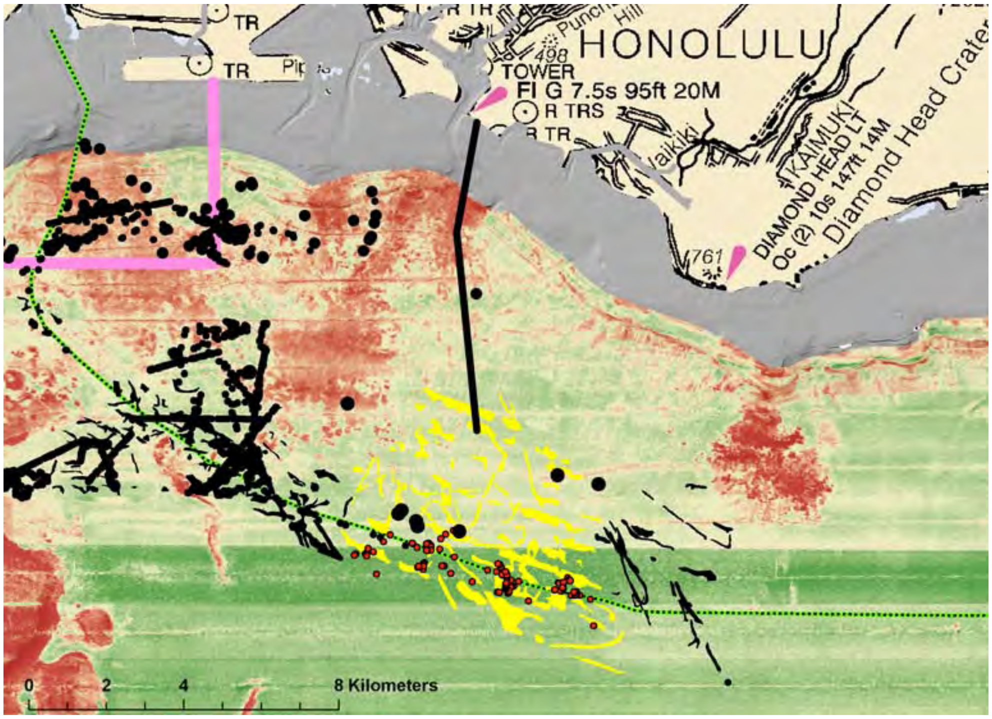


Fig 7: Suspected and known obstacles to the installation of a power cable along the previously recommended route. See text for description.

<u>Objective 2: Sidescan sonar mapping of the potential routes from east Oahu to Molokai/Lanai</u>

The map in Figure 8 shows the new sidescan data acquired along recommended and alternate routes crossing the Ka'iwi Channel between Oahu and Molokai/Lanai. The solid black line is the potential route from Kaneohe Air Corps Marine Station (KACMS) to Ilio Pt, NW Molokai. The dashed black lines include alternate routes from KACMS to Ilio and around Laau Pts. The routes and the sidescan data are overlain on multibeam backscatter data that was available at the time of the survey. Of particular importance in this area is how the cable should traverse drowned reef terraces located in the middle of the channel, which are shown as red colored backscatter data. These features are solid carbonate rock and it is assumed that instead of being buried, the cable will need to be laid on the surface of these features. However, it's unclear whether the contractor installing the cable will prioritize minimum surface exposure over minimum change of slope. Therefore, we provide two options for DBEDT to consider based on an analysis of the sidescan data along with additional multibeam backscatter data processed during the preparation of this report (Fig 9). Option A shows the route through the narrowest part of the northern terrace that minimizes the cable's surface exposure. Option B takes the route through a wider but flatter part of that terrace further to the west. Both options converge in a sand field on the southeast side of the terrace. At a crossing point, the exact location of which is discretionary, the route splits into two branches, one turning ESE toward Ilio Pt, the other passing south around Laau Pt. Both of these branches must traverse a second terrace further east, each at a different location that was selected on the basis of terrace width and slope.

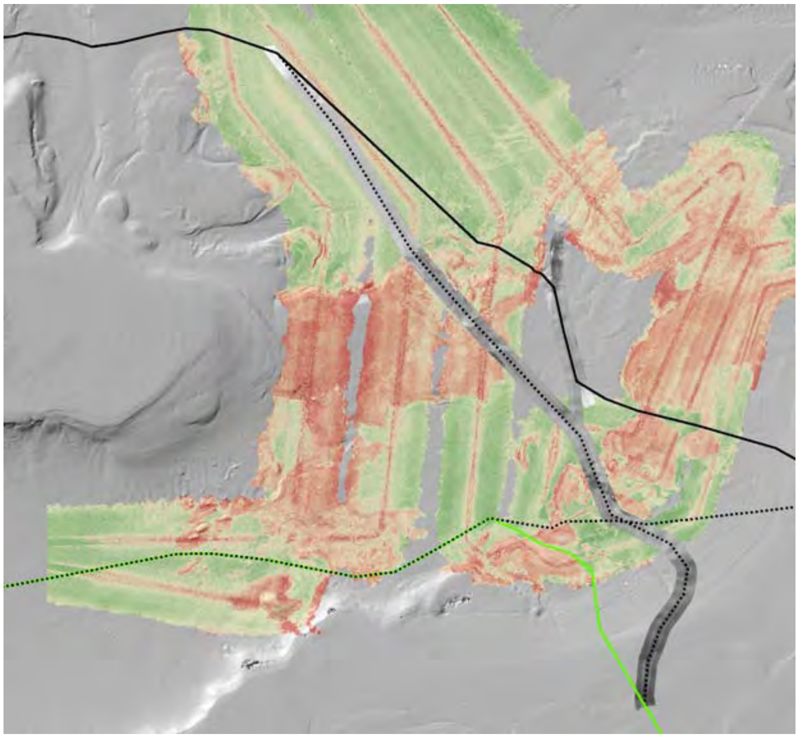


Figure 8: Map of the Ka'iwi Channel between Oahu and Molokai showing the new DT-1 sidescan data (light-to-dark gray swaths) obtained along the potential (solid) and alternate (dashed) routes, overlain on the multibeam backscatter data (red-green) used in Taylor, 1999.

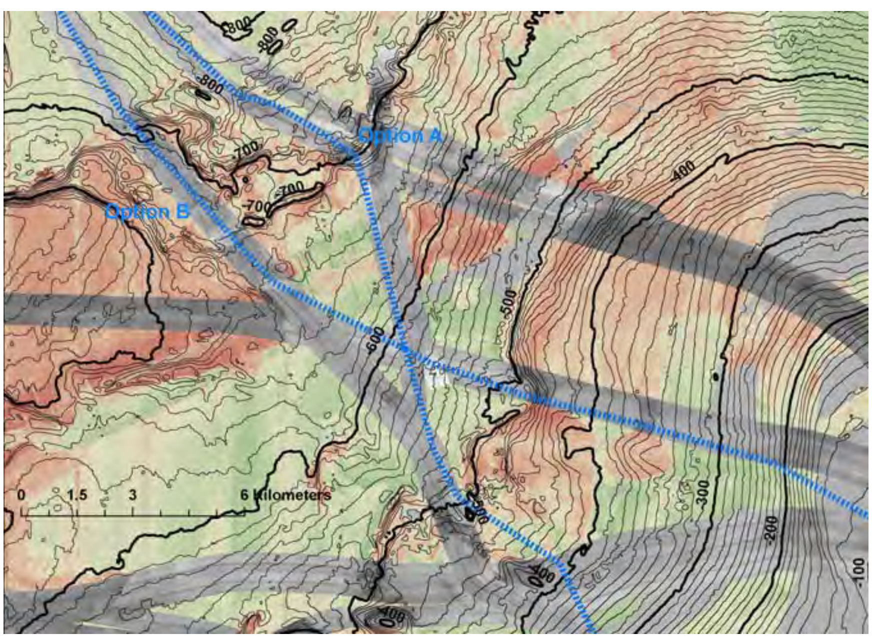


Figure 9: Close up of optional routes A and B for traversing the drowned reef terraces in the Ka'iwi Channel. Note also the inclusion of additional processed multibeam backscatter data.

The existence of two optional route segments (A and B) each of which can connect to two different potential routes (from Kaneohe to NW Molokai or to Lanai) allows four possible combined routes. The two figures following show two of those four possibilities from Kaneohe: to NW Molokai in Figure 10 and the most direct potential route to Lanai in Figure 11. Given that we no longer recommend a cable route south of Oahu to Pearl Harbor/Honolulu, the latter (with an option A alternate segment) becomes our recommended route from Oahu to Lanai, just as the former (with an option B alternate segment) remains our recommended route to NW Molokai.

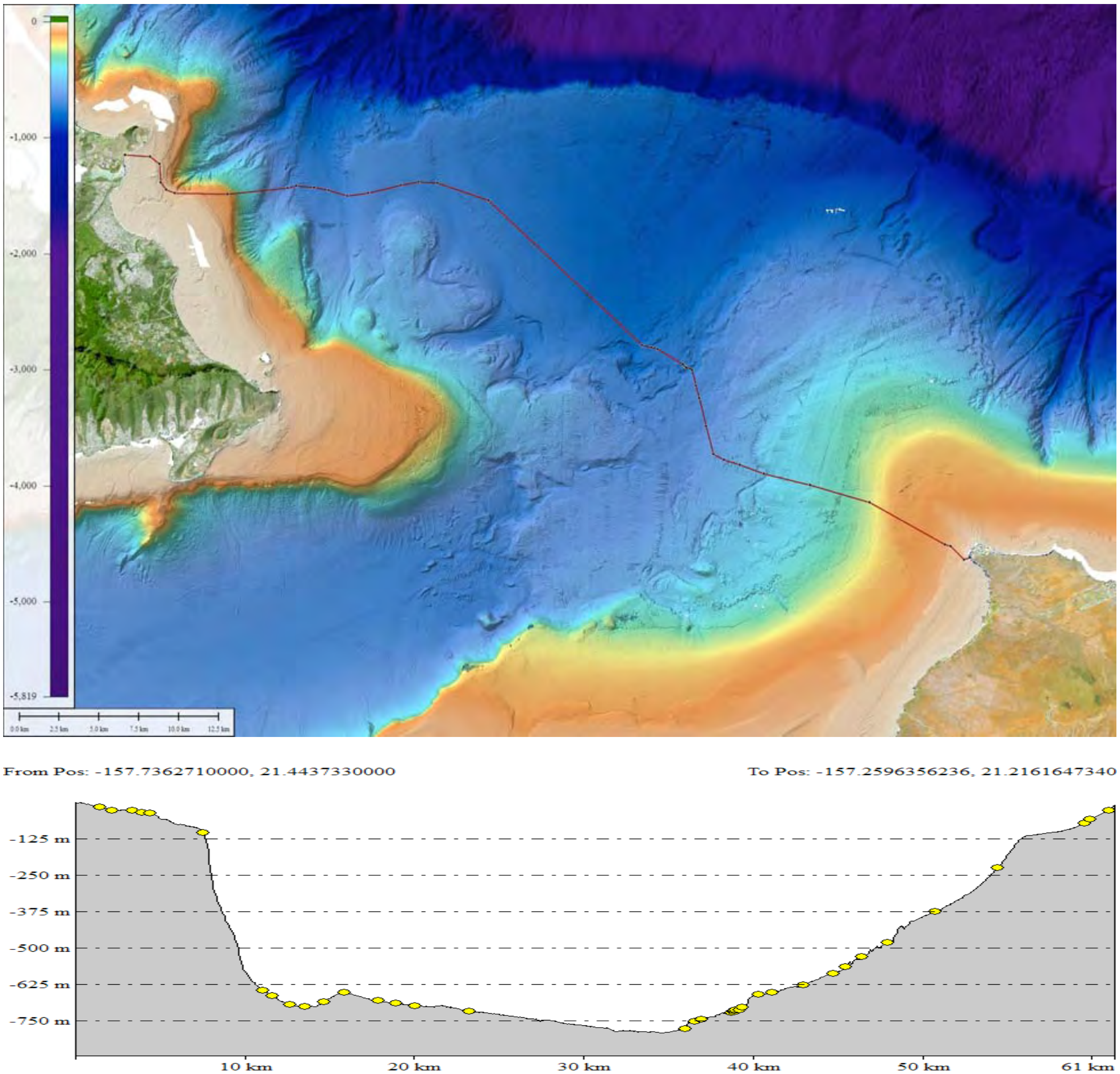


Figure 10: Recommended potential power cable route and associated depth profile from Kaneohe to NW Molokai (using optional segment A).

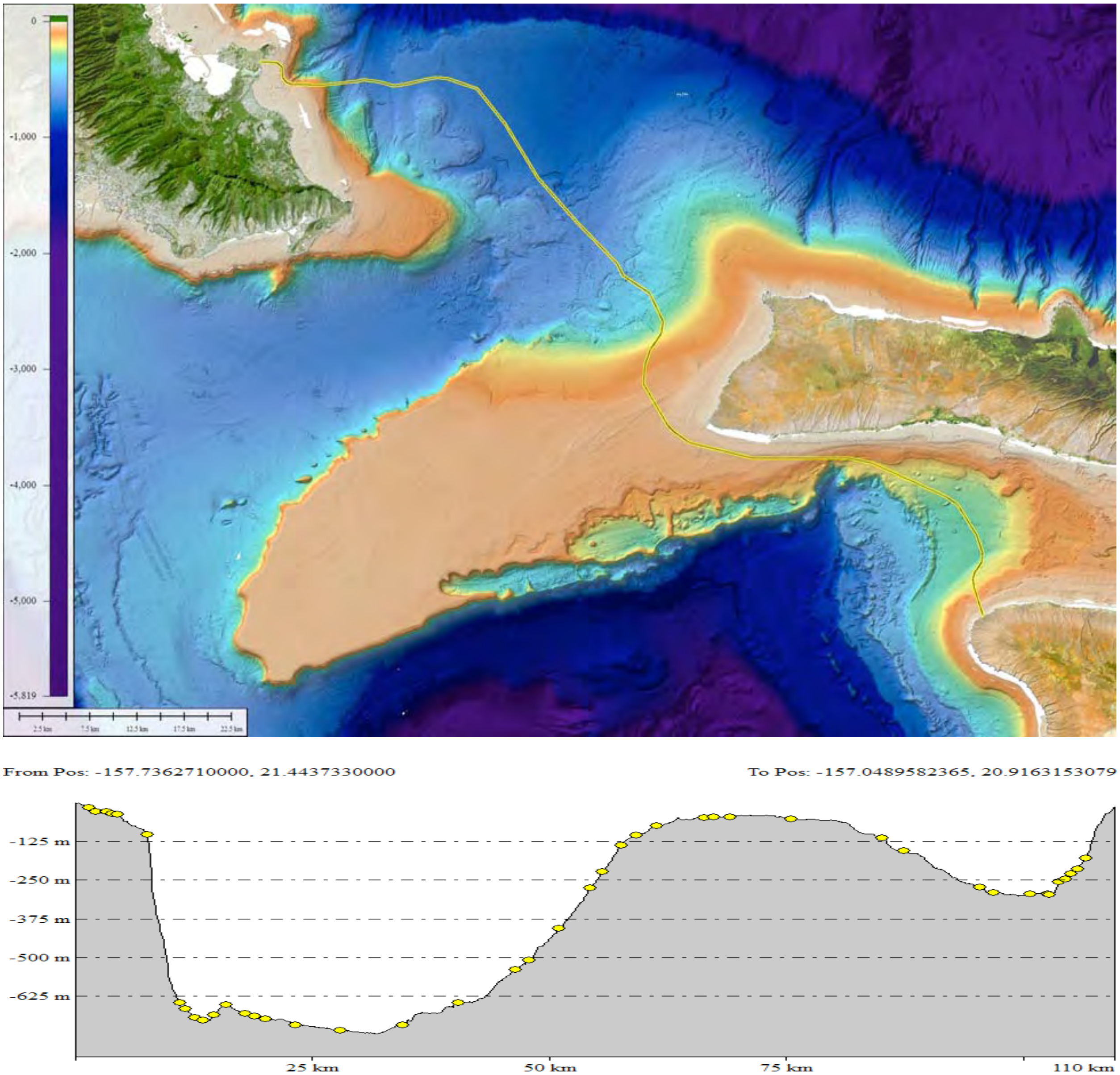


Figure 11: Recommended potential power cable route and associated depth profile from Kaneohe to Lanai (using optional segment B).

Discussion and Conclusions

NRL's DT-1 deep-towed sidescan sonar system was used successfully to further map the disposed munitions field south of Oahu and potential cable routes across the Ka'iwi Channel. The mapping of the munitions field did not reveal a clear detour north of the previously proposed route. "Speckle trails" believed to be munitions were found throughout the newly mapped area and overlapped the location of a proposed deep seawater pipe system. The proposed location of the pipe intake at 544m depth creates a northern boundary for a power cable approaching Pearl or Honolulu Harbors from the east. To lay a cable south of the intake, a swath would need to be cleared through both the munitions and extensive dredge spoil deposits, which may be both costly and difficult to achieve (risking the safety of equipment and personnel).

A detour south of the currently proposed cable route may be possible, however a lack of sidescan data for that area precludes detailing that alternative at this time. It is likely that the known munitions field extends southward for a considerable distance and that clearing a swath would be necessary for this option as well.

In general, the seafloor south of the area from Diamond Head to Pearl Harbor is a large disposed debris field that poses a significant challenge for the installation of an inter-island power cable along the south coast of Oahu. At the present time, a satisfactory route through this area has not been identified. It may be possible to route a cable around the field of volcanic rocks south of Diamond Head then northwest and across the slope to near the channel entrance to Kewalo Basin (staying east of the proposed deep seawater pipe off Kakaako, west of another contemplated off the Ala Wai canal, and west of the Humpback Whale Sanctuary). Even so, whether there is an acceptable route (and converter station location) from there to Iwilei would still need to be addressed.

On the other hand, the new data obtained along the potential cable routes through the Ka’iwi Channel were useful in determining the best locations for traversing hard substrate reef terraces where the cable may need to lay on the seafloor. Two optional route segments were identified and detailed from which DBEDT and its contractors may select. These new data will shortly be added to the GIS project currently being prepared for web access by DBEDT and its contractors.

Acknowledgements

This report, and the data on which it is based, is the result of substantial efforts at sea and ashore by members of several SOEST units, including the UH Marine Center, especially the captain and crew of R/V Ka’imikai-O-Kanaloa, the Hawaii Undersea Research Lab, notably Chris Kelley (Figure 2) and John Smith, the Hawaii Mapping Research Group, particularly Paul Johnson, Associate Dean for Research Sandy Shore, and members of the Naval Research Lab. Most of this and the previous 2010 Ocean Floor Survey Extension report was drafted by Chris Kelley, though the interpretation is joint with the P.I., who bears responsibility for its content.

Citations

Taylor, B. 2009. Hawaii “Inter-island cable ocean floor survey” Final Report, November, 2009.

Taylor, B. 2010. Hawaii inter-island cable “Ocean floor survey extension” Technical Final Report, submitted to DBEDT July, 2010.

Erratum

In the preparation of this report, it was realized that Figure 13 in Taylor (2009) shows the recommended cable route from Kaneohe to NW Molokai but, incorrectly, the depth profile from Pearl Harbor to NW Molokai. The correct depth profile is shown in this report in Figure 10.

Report 4

November, 2010

Technical Final Report

"Identification of Alternate Cable Routes South of the Islands of Molokai and Oahu"

From

University of Hawaii

Brian Taylor, Principal Investigator

To

State of Hawaii

Department of Business, Economic Development and Tourism

November, 2010

Introduction

This is the fourth of four technical reports submitted by The University of Hawaii's School of Ocean and Earth Sciences and Technology (SOEST) to The State of Hawaii's Department of Business, Economic Development, and Tourism (DBEDT) on the findings of 3 contracted surveys along the proposed routes for an inter-island undersea power cable between the islands of Molokai, Lanai, Maui, and Oahu. The first "2-part" survey was conducted in June and July, 2009, and obtained high resolution towed multibeam and sidescan sonar data as well as video camera footage along most of the proposed route system. During the first part, multibeam and sidescan sonar data were collected off The University of Hawaii's research ship R/V *Kai'imikai-o-Kanaloa* (KOK) with the use of the Naval Research Laboratory's (NRL) deep towed sonar system DT-1. Both types of data were on the order of 1m resolution and were incorporated into a Geographic Information System (GIS). The second part was conducted off the same ship and collected video camera footage with the use of a custom built towed camera system owned by Dr. Roy Wilkens of SOEST. The findings from both parts of this survey were submitted in the first technical report to DBEDT (Taylor, 2009) and included recommended modifications to the routes to avoid obstacles including hard substrate features and possible manmade metallic objects. Of particular concern was a possibly extensive disposed munitions field along one 4 mile section of the route south of Oahu, further east than known disposal areas. The sidescan sonar data showed an extensive pattern of "speckle trails", which elsewhere have been confirmed by submersible to be disposed munitions (see http://hummaproject.com/team.php). As the towed camera passed through these trails, it recorded a number of small (i.e. 1 meter long) aerial bombs that appear to match archival photographs of World War I era chemical weapons. At least 16,000 MK47A2 100 lb mustard gas bombs were disposed of south of Oahu in 1945-46, the exact location of which had never been determined.

The possible presence of chemical munitions along the route leading into Pearl Harbor poses a serious complication during the installation of the cable, and therefore DBEDT contracted SOEST to conduct a second survey to identify the objects that appeared on the towed video camera footage. This survey was conducted January 25-27, 2010 and involved the use of the Pisces IV and V submersibles along with the RCV-150 Remotely Operated Vehicle (ROV) operated by the Hawaii Undersea Research Laboratory (HURL). Over 100 bombs were documented that were tentatively identified as MK47A2s based on their size, shape, and the presence of green paint bands on several that confirmed they contained chemical agent. The findings, provided last month in a second technical report to DBEDT (Taylor, 2010a), indicated the need to detour the route around the bomb field, preferably to the north. However, the extent of the field along the north-south axis was unknown.

In February, 2010, DBEDT was informed that NRL's DT-1 towed sonar system was returning to the islands for a Navy-funded survey off Barber's Point, Oahu and that they could "piggyback" additional mapping days onto that project, saving the considerable costs associated with mobilizing the equipment and staff from the east coast. Therefore, DBEDT contracted SOEST to conduct a third survey aimed at obtaining sidescan sonar data 1) north of the bomb field and 2) along primary and alternate routes between east Oahu and Molokai. This survey was conducted in March, 2010 and found evidence of substantial quantities of disposed ordnance north of the known bomb field. The findings were provided in a third technical report to DBEDT (Taylor, 2010b).

Following the submission of those reports, DBEDT learned that it may not be able to obtain a permit to install the cable within federal waters of the Hawaiian Islands Humpback Whale National Marine Sanctuary (HIHWNMS). DBEDT therefore contacted SOEST and requested recommendations for alternate routes through the HIHWNMS that stayed entirely within the state's 3 nautical mile jurisdictional boundary, where a permit could be obtained. DBEDT also reported that the Hawaiian Electric Company (HECO) would favor a south Oahu landing site near Honolulu Harbor and the Iwilei sub-station instead of Pearl Harbor. DBEDT therefore requested SOEST also recommend a route to Honolulu Harbor that avoided as much of the disposed ordnance as possible. These recommendations are provided below in this fourth of four technical reports.

Methods

Unlike the first 3 reports, the findings of this report are not based on new surveys, but rather from re-examination of data already existing in the GIS project created for DBEDT. In addition to these data, unprocessed backscatter data from the 2009 R/V Ahi multibeam sonar survey south of Molokai were processed by Paul Johnson of the Hawaii Mapping Research Group (HMRG) for use in identifying an alternate Maui route. Furthermore, high resolution sidescan sonar data obtained from Honolulu Seawater Air Conditioning, LLC (HSAC) were examined to help identify a route that approaches Honolulu Harbor.

Results

Three changes to the previously proposed routes were necessary to comply with DBEDT's request. Figure 1 provides an overview of these changes while Figs 2, 3, and 4 provide more detailed views of the various sections. In Fig. 1, the unchanged portions of the routes are shown as yellow lines while the changes are shown in red. The state 3 nautical mile boundary is shown in green and the HIHWNMS is shown as the blue cross-hatched areas. The first two changes were necessary to keep the routes within state waters as they transited through the HIHWNMS. Of these, the route from Waiakane, south of Molokai, to Kahalui, Maui was diverted north to keep it inside state waters until it cleared the sanctuary on the eastern side of the Pailolo channel. Secondly, the direct route from Kaneohe to Lauu Pt on the southwest corner of Molokai was diverted to the north closer to Ilio Pt in order to avoid federal waters of the sanctuary. The third change was a proposed new route toward a Honolulu Harbor landing site as an alternative to the previously proposed Pearl Harbor landing site.

In Figs. 2, 3, and 4, route sections that remained unchanged are shown as yellow dashed lines, the changed sections are shown as red dashed lines, the state's 3-mile boundary is shown as a solid green line, and HIHWNMS is shown as blue cross-hatched areas. The multibeam backscatter data (acoustic imagery) color ramp ranges between red (hard substrate) to green (soft substrate).

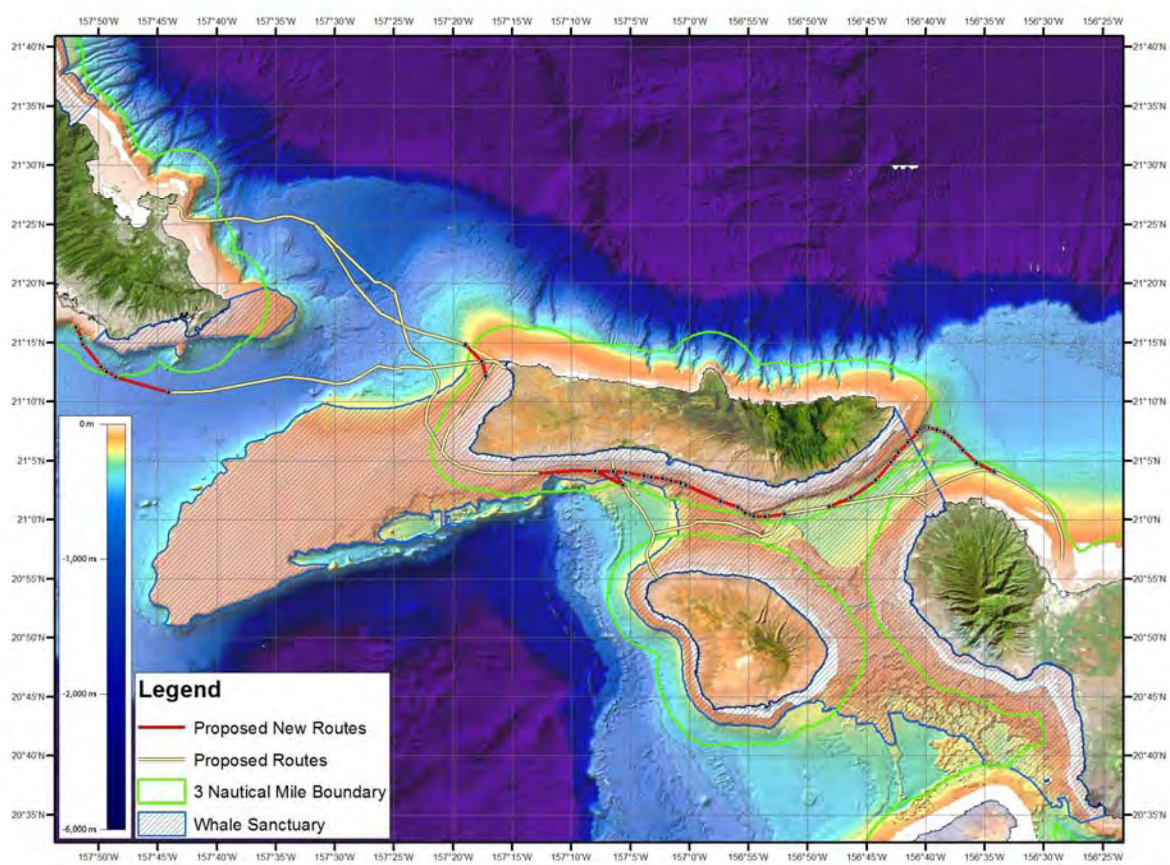


Fig 1: Overview of the changes in the proposed routes.

<u>Alternate Route 1: Waiakane, Molokai to Kahalui, Maui</u>

Fig. 2a shows that at Waiakane, the alternate route diverts from the original route at approximate -156° 13', roughly following the 100m contour rather than dropping down to the next lower terrace. To save on the length of the cable, the branch point to the Lanai landing was moved to a position further east that is still outside of the HIHWNMS. In order to avoid sharp ingresses and egresses along the 100m contour, the route moves upslope south of Kanakakai, gradually coming as shallow as 50 m south of Kawela (Fig 2b). In this area, the route must traverse hard substrate for approximately 2.5 miles in order to remain in state waters. This terrain is presumed to be relatively flat carbonate hardpan or a large bed of rhodoliths (red calcareous algae concretions), both of which could be responsible for the high backscatter return. Between -156° 55' and -156° 54', the route descends into the basin of Pailolo channel. The exact location is a small ingress or gully near the 3-mile limit (Fig. 2c). Other locations appeared to have steeper slopes at more obtuse angles to the route and were therefore considered unsatisfactory.

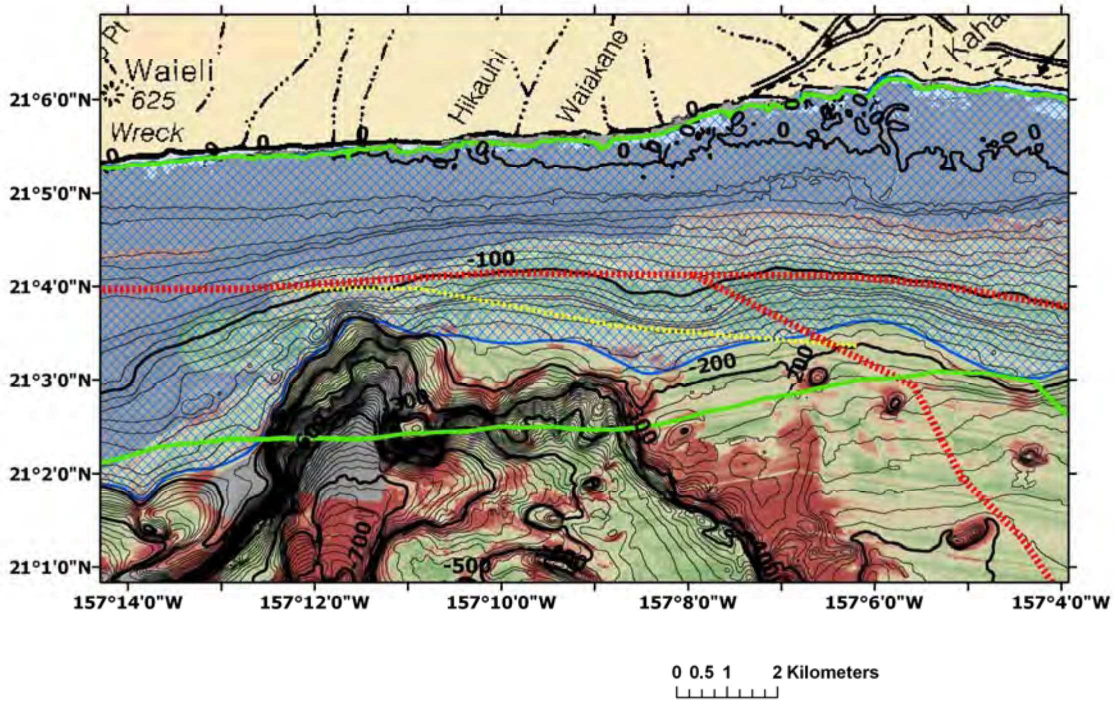


Fig 2a: The western diversion point from the original cable route through the Kalohi channel.

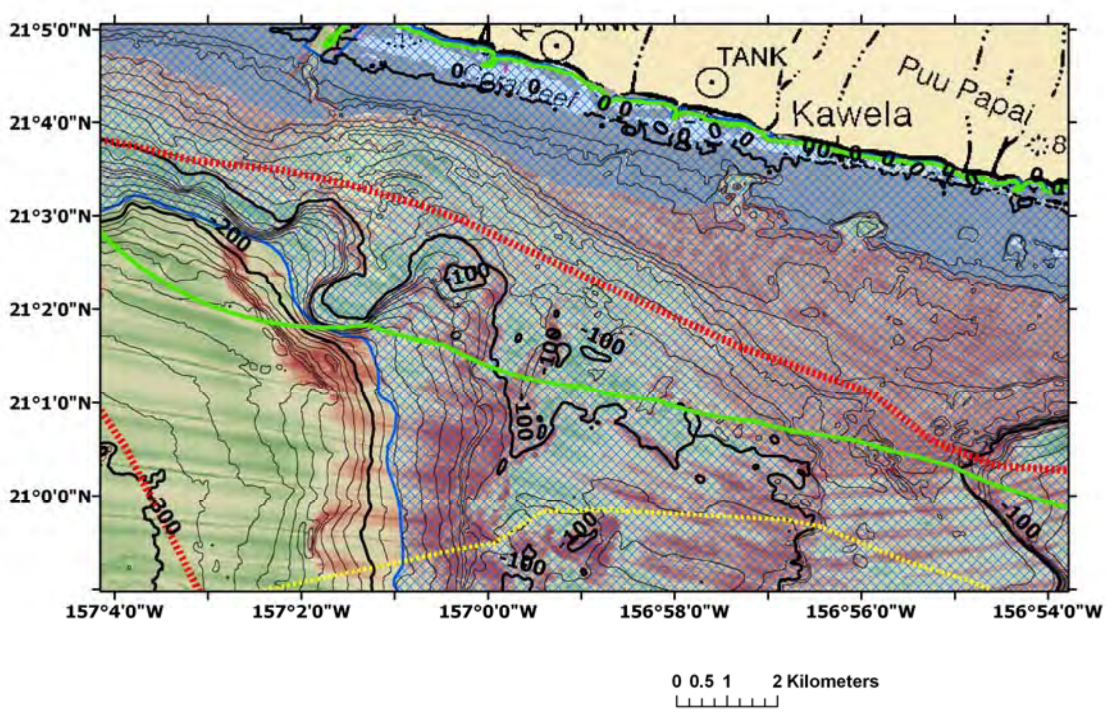


Fig 2b: The alternate cable route at the junction between the Kalohi and Pailolo channels.

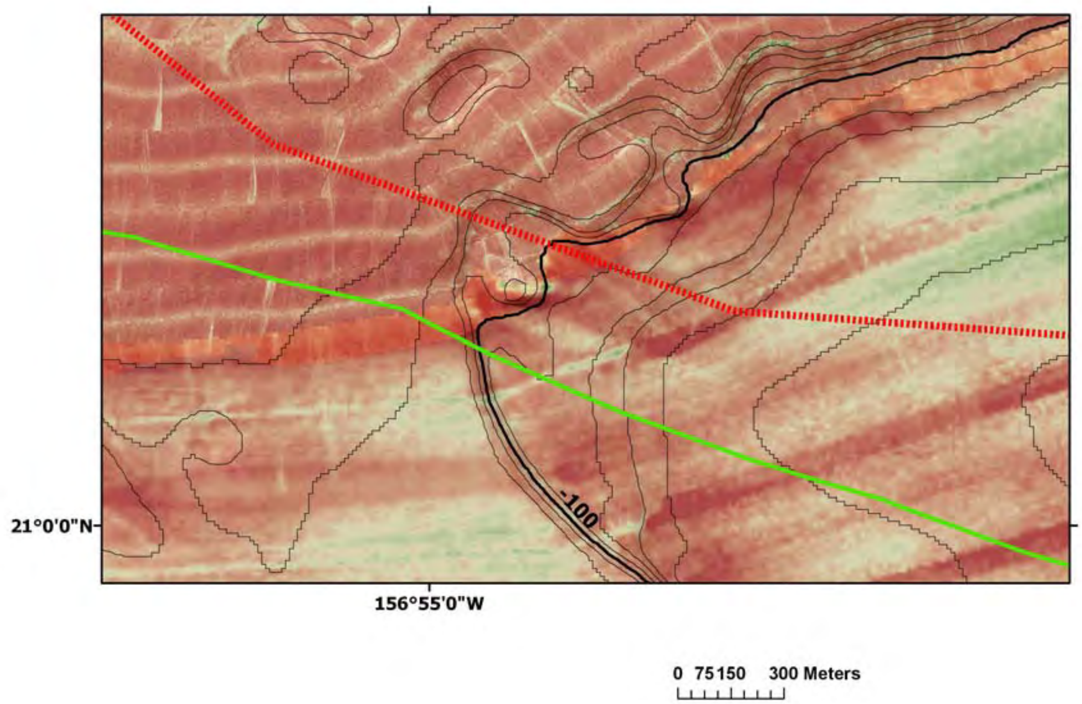


Fig 2c: Detail of the alternate cable route descending into Pailolo channel.

The alternate route within the western and central sections of Pailolo channel is unremarkable, traversing soft sediment at a relative constant depth of just over 200m similar to (and partially duplicating) the original route (Fig 2d). However, the new route becomes more complicated at the eastern end of the channel due to challenging topographic changes created by a substantial area of hard substrate located in the center of the channel entrance (Fig. 2e). There does not appear to be any better way to traverse this terrain than to bring the cable upslope to approximately 150m over a mixed substrate of soft and hard material. It's unlikely that the cable can be buried within this 3 mile stretch. The end of this area coincides with the end of the HIHWNMS at which point the route can be turned southeast in order to connect up to the original route leading into Kahalui Harbor, Maui. This last stretch appears to be primarily sediment.

Figs. 2 f and g provide an overview and depth profile of the entire route from Ilio Pt to Kahalui, Maui. The first half of the 130 km route is less than 100m deep with the latter half dropping down to a maximum of 325m outside the eastern entrance to Pailolo channel.

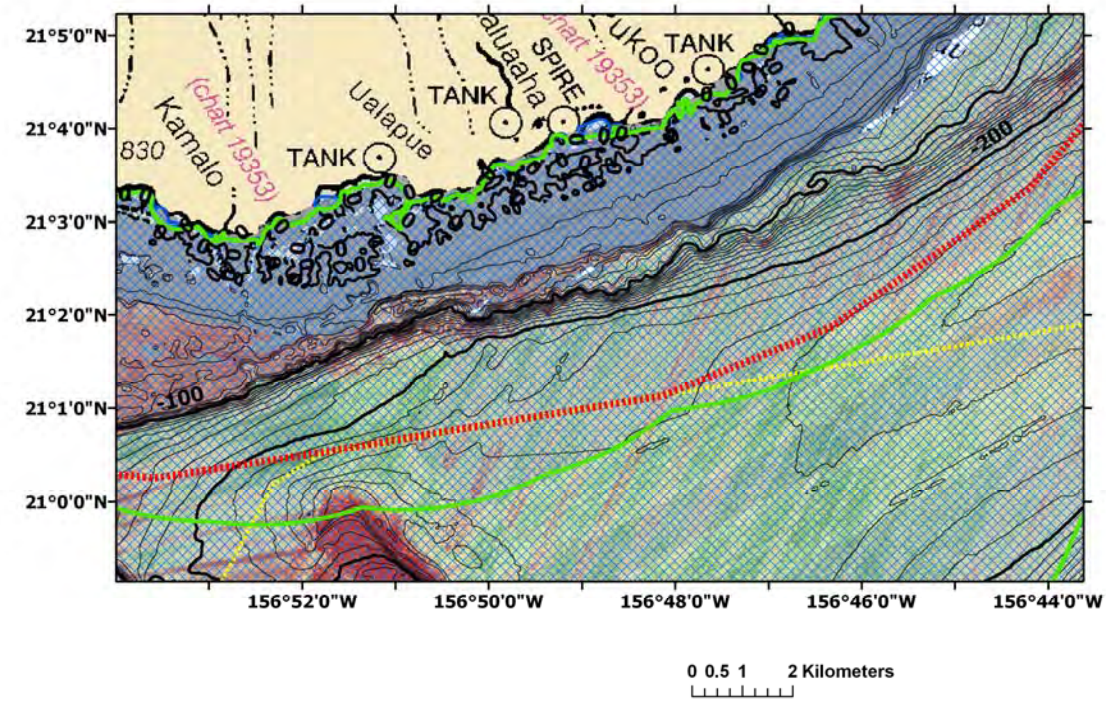


Fig 2d: Detail of the alternate cable route in Pailolo channel.

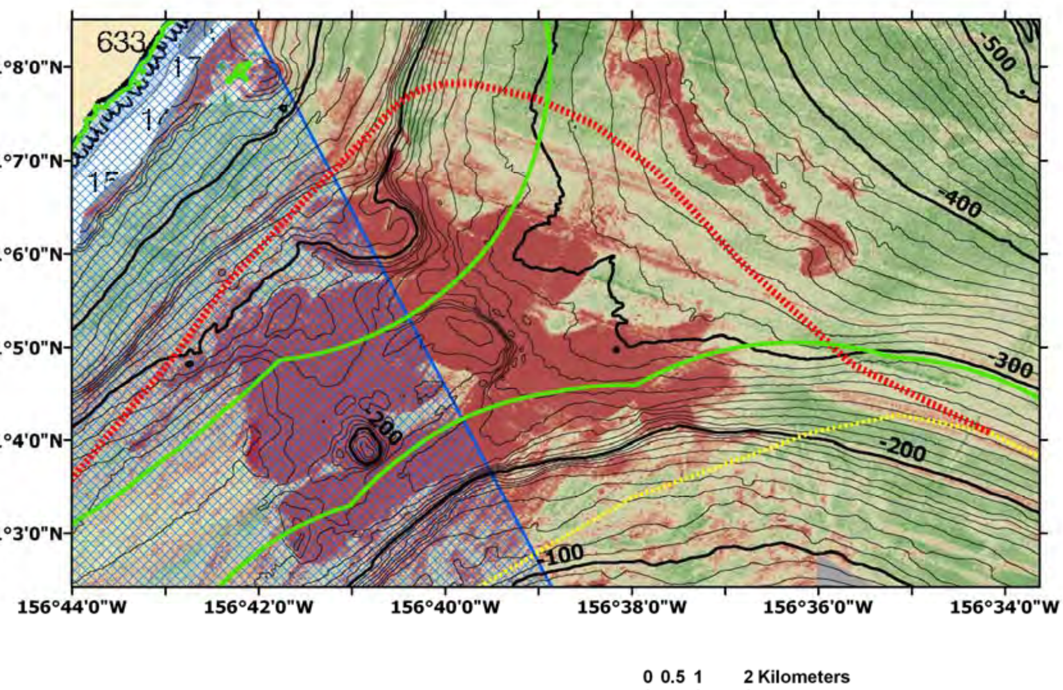


Fig 2e: Detail of the alternate cable route at the eastern end of Pailolo channel.

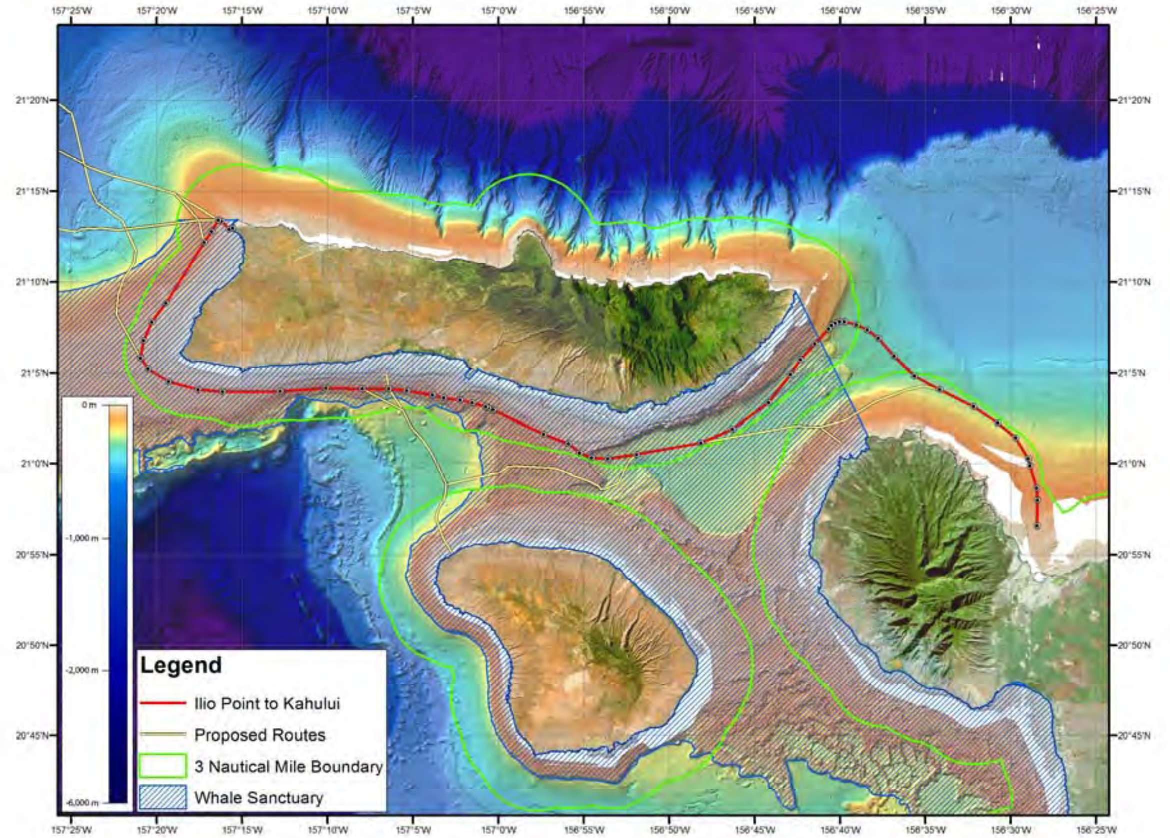


Fig 2f: Overview of the new route from Ilio Pt, Molokai to Kahalui, Maui.

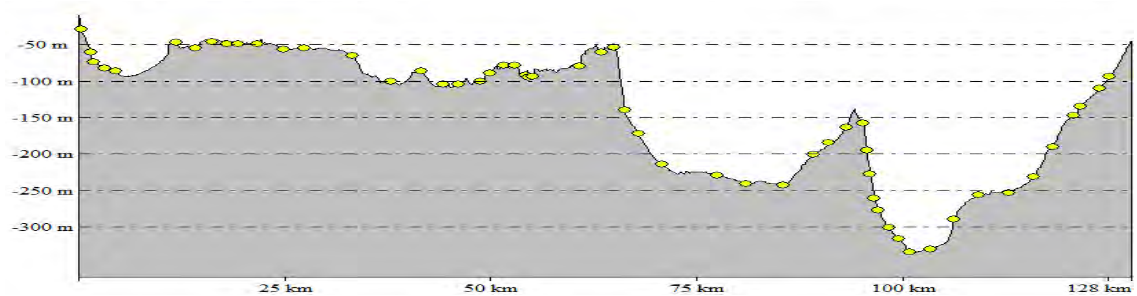


Fig 2g: Depth profile of the new route from Ilio Pt Molokai to Kahalui, Maui

Alternate Route 2: Kaneohe, Oahu to Laau Pt, Molokai

Fig. 3a provides a more detailed view of the Kaneohe to Laau Pt route change near the northwest corner of Molokai. In order to avoid federal waters of the sanctuary, the route must continue further east toward Ilio Pt before branching south to connect to route C along the west coast of Molokai. This is a relatively minor alteration that will likely only be used if an Ilio Pt landing does not occur (Fig. 3b). The multibeam and sidescan coverage is not complete in this location however from the data that is available, the new diversion of the route appears to traverse soft substrate and therefore should not pose any additional technical problems for the cable installers. Figs. 3 b and c provide an overview and depth profile of the entire route between Kaneohe and Lanai that includes this new section. The maximum depth of the route (>700m) is reached in the first section between Kaneohe and Ilio Pt. The latter half of the route is generally shallower than 125 m except where it crosses the floor of the Kalohi channel where it drops to just over 300m.

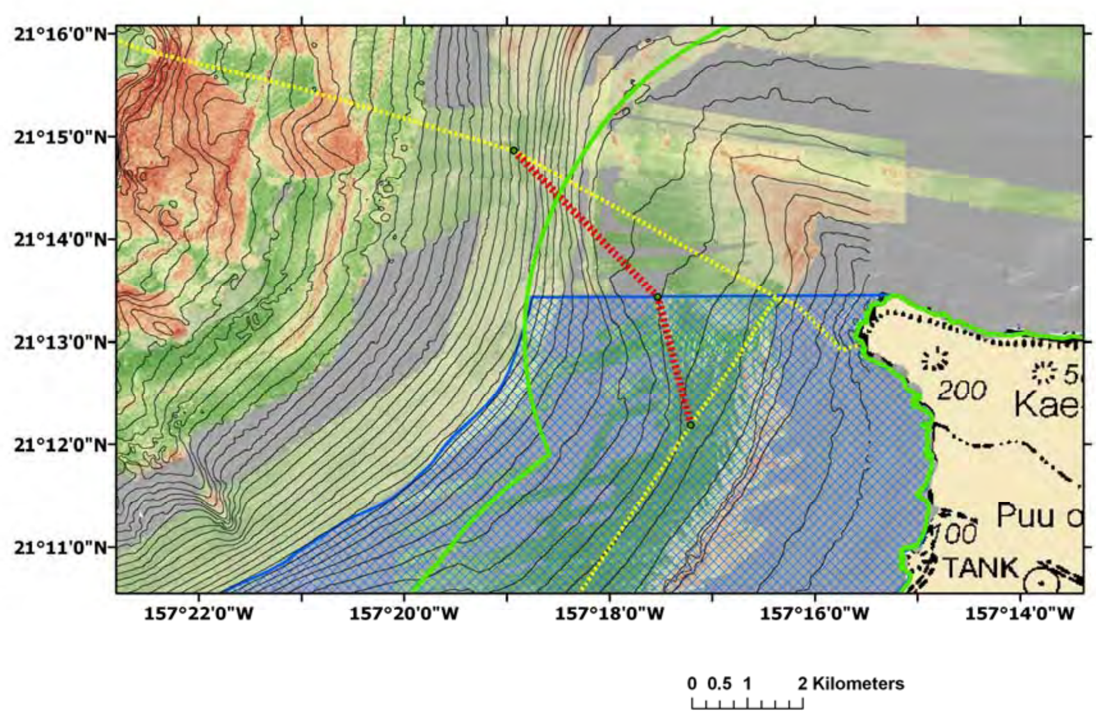


Fig 3a: The new segment connecting routes A2 and C on the route between Kaneohe and Lanai.

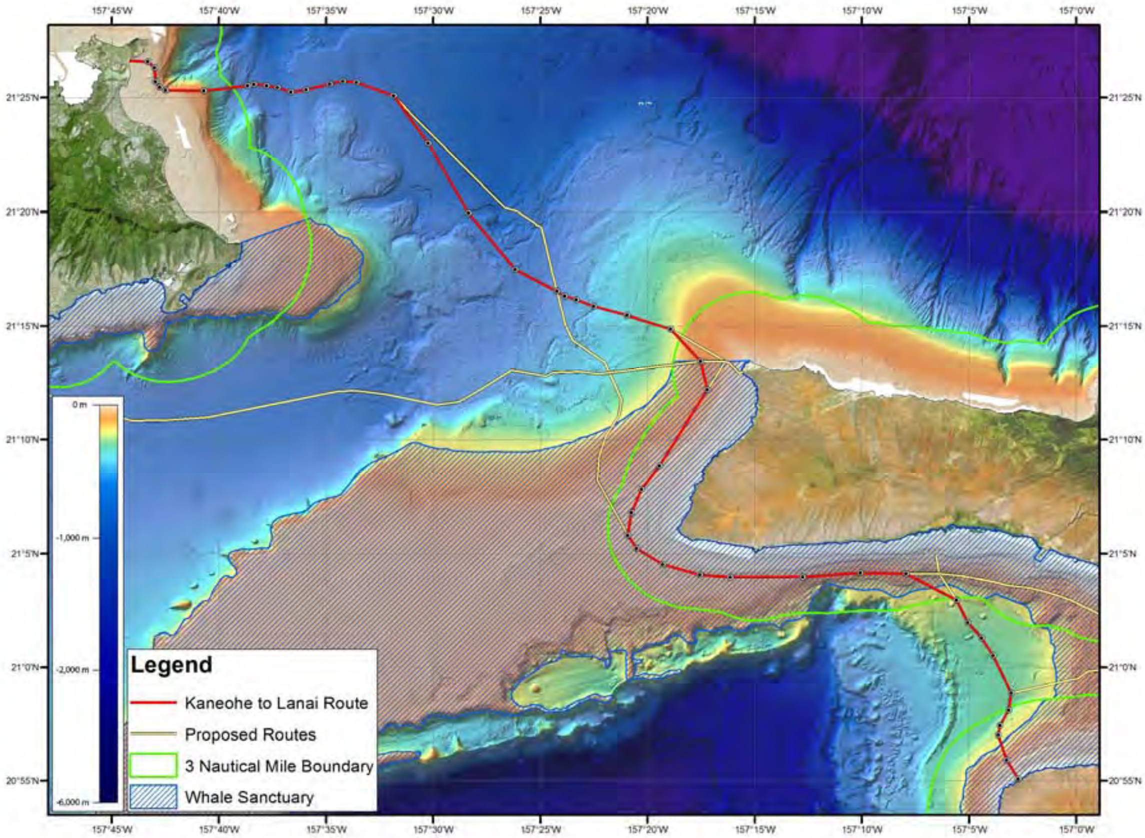


Fig 3b: New route from Kaneohe to Lanai that avoids the federal waters of the HIHWNMS.

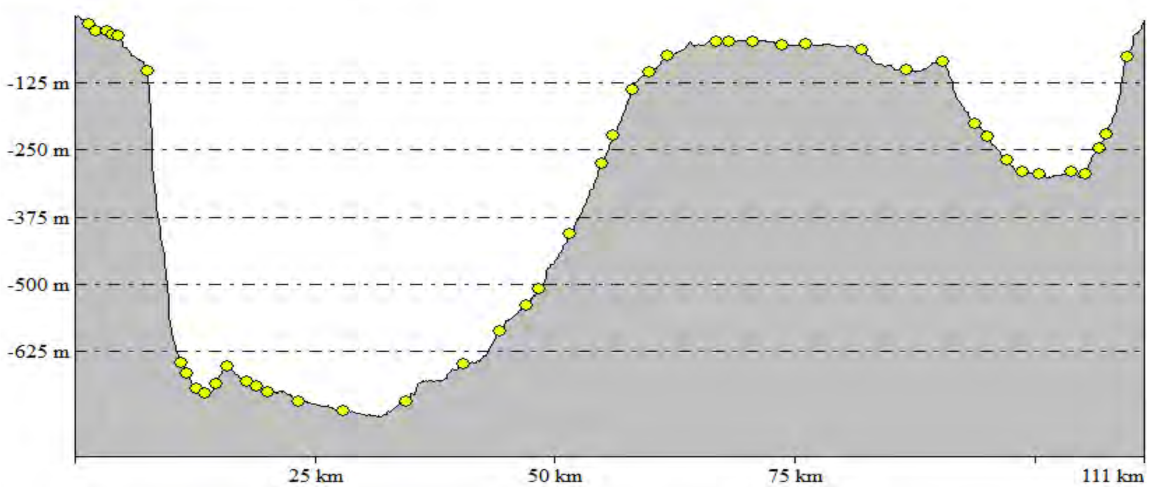


Fig 3c: Depth profile of the new route from Kaneohe to Lanai.

Alternate Route 3: South Oahu toward Honolulu Harbor

Figs. 4a-e provide various views of the alternate route around the ordnance field and up toward the entrance of Honolulu Harbor. This new route diverges from the original route at approximately -157° 44’, where it angles northwest over flat sediment substrate (Fig 4a,b). This section is not believed to contain any disposed ordnance or other significant obstacles. Once it clears the large rocky feature extending south from Diamond Head, the route bends further north, running between two suspected conventional ordnance trails shown as solid black polygons (Fig. 4c). These areas along with suspected chemical ordnance areas (yellow polygons), were revealed by high resolution sidescan sonar data obtained during the third DBEDT survey. These data only extended to where the new route crosses the 570m contour. No high resolution data exist from that point to where the route goes off the northern side of the image. As a result, the presence of ordnance and/or obstacles in this section of the route cannot be discounted, and in fact, may be as much of a problem as it is for the original route leading into Pearl Harbor. Here, we are only able to recommend a route into Honolulu Harbor based on multibeam sonar data, which does not have the resolution to detect objects as small as ordnance.

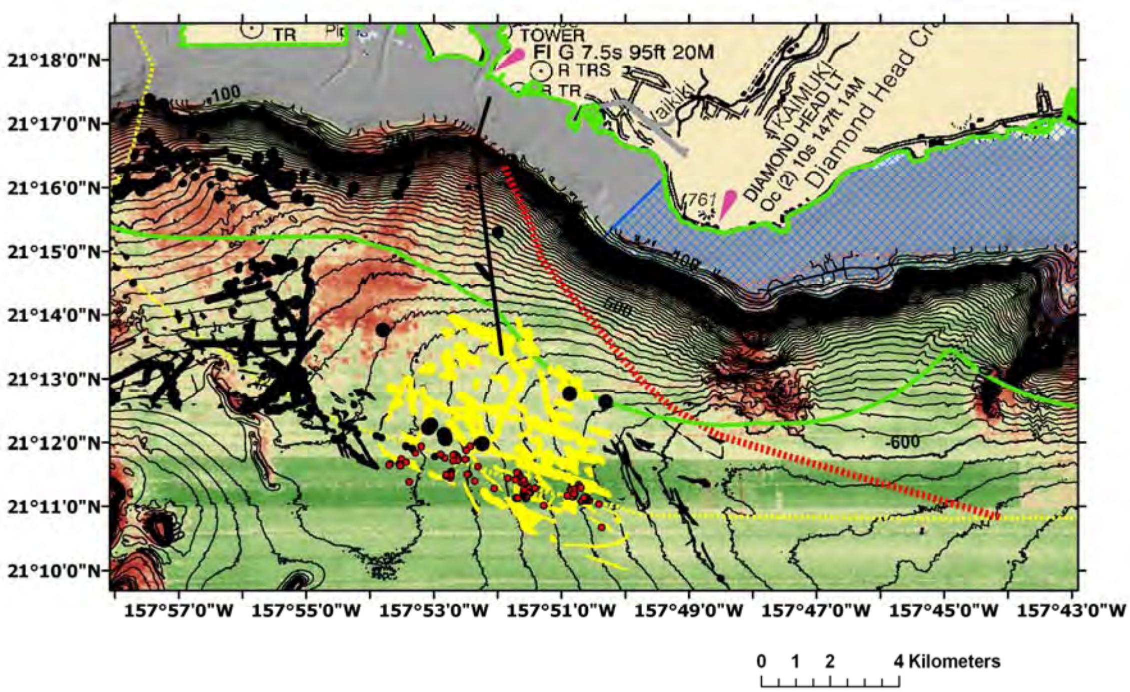


Fig 4a: Overview of the new route toward Honolulu Harbor. Suspected conventional and chemical disposed ordnance areas are shown as black and yellow polygons, respectively. Large black dots are wrecks and other manmade obstacles. Small red dots are confirmed chemical ordnance. The black vertical line in the upper left corner of the image is the proposed route for the Honolulu Seawater Air Conditioning Pipe.

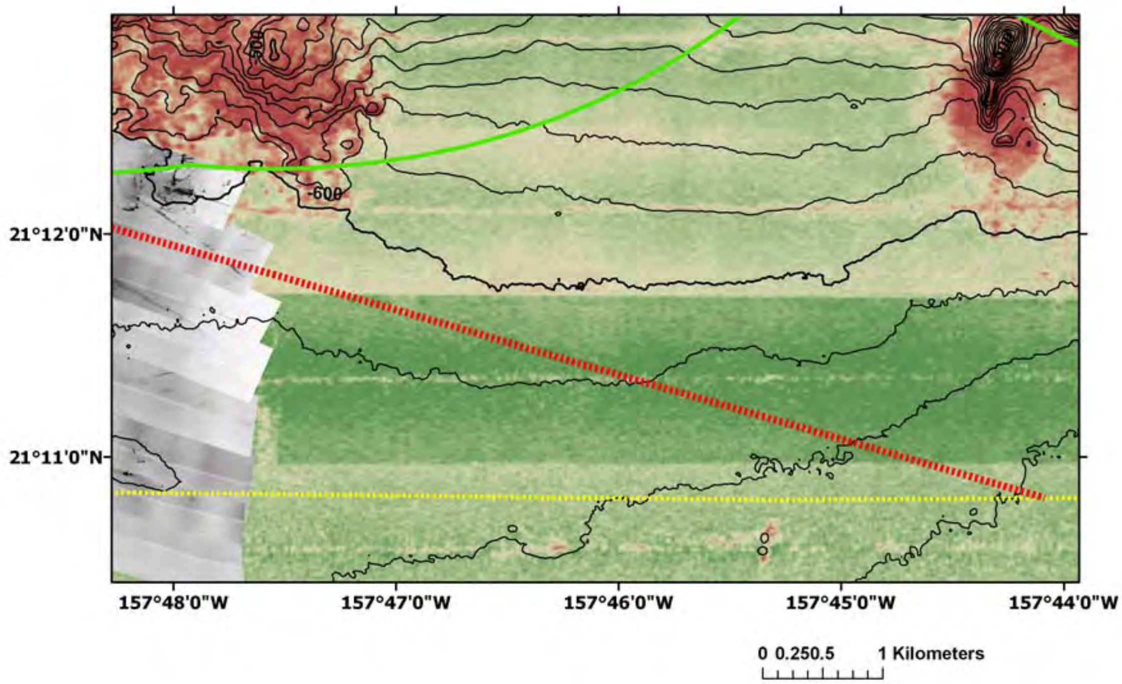


Fig 4b: Detail of the eastern end of the new route where it diverges from the original route to Pearl Harbor.

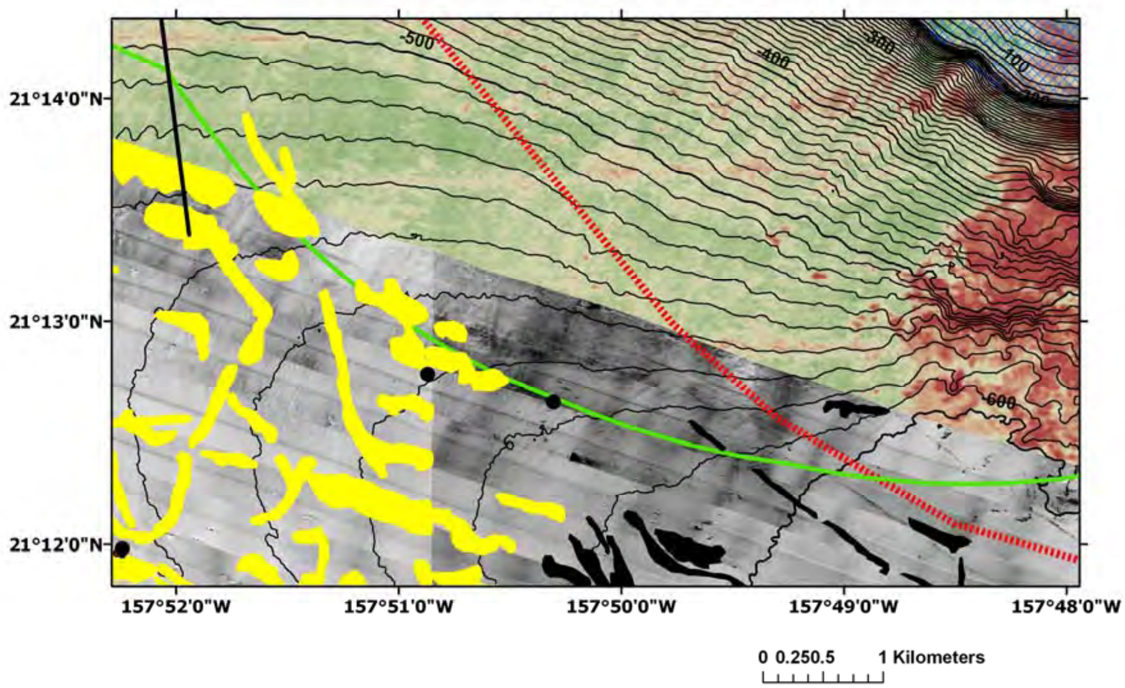


Fig 4c: Detail of the middle section of the route just southwest of Diamond Head.

The final section of the route shown in Fig. 4d extends up to an approximate depth of 230m and ends short of the entrance to Honolulu Harbor. This was purposely done because of our uncertainty regarding the landing site as well as how the cable will be installed over substantial dredge-spoil deposits, a large carbonate terrace, and the HSAC pipe. As with the previous section of the route, there is concern over what ordnance and obstacles may be present in this section. Examination of the HSAC data indicates that dredge-spoil and other obstacles are most likely present from the end of our drawn route to at least the top of terrace at 110m.

Figure 4e provides a view of the area from the end of the route into Honolulu Harbor. This image was included to illustrate the perceived problem with connecting the cable to a converter station located in Iwilei. Specifically, the cable must either reach the station by going through the harbor itself or by landing east of the harbor entrance and going overland to the station. The harbor is and will continue to be actively dredged, which seemingly puts any cable in the harbor at risk of being damaged by the dredging equipment. It is furthermore unclear to us whether

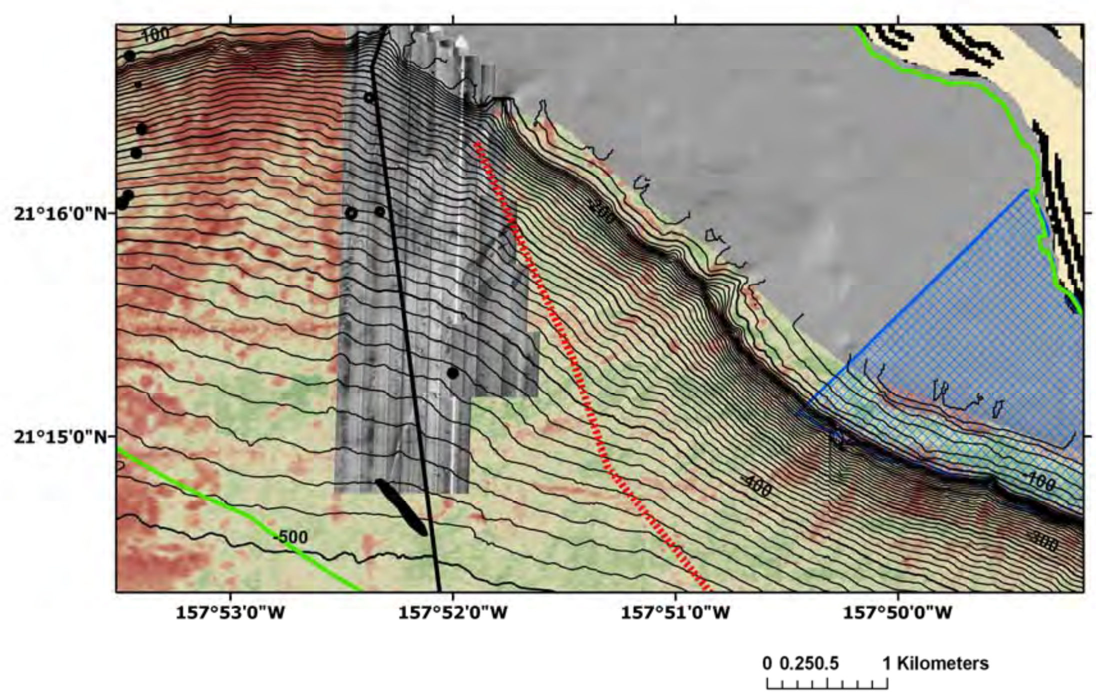


Fig 4d: Northwestern section of the route as it approaches Honolulu Harbor.

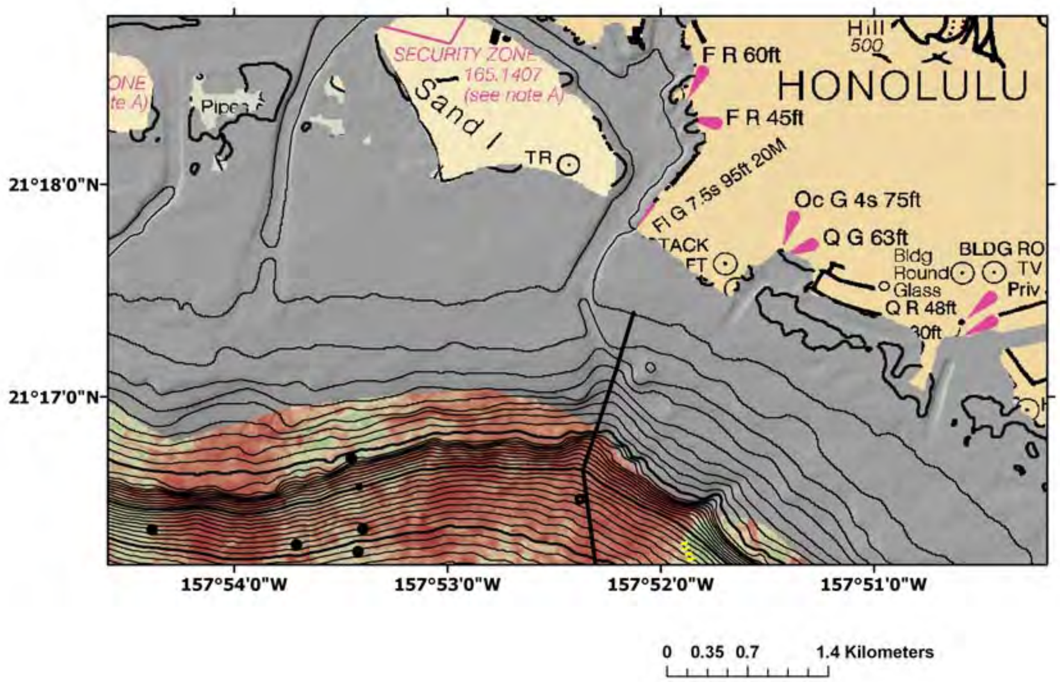


Fig 4e: Detail of the area north of the end of the route to Honolulu Harbor.

DBEDT would even have the option to extend the cable overland from the eastern side of the harbor entrance. One other possible solution not previously discussed with DBEDT is a landing on Sand Island, extending the cable over the bridge to the western side of the harbor where it would go overland to the Iwilei station. However, the extent of the reef outside of Sand Island may make this option unfeasible.

Figs. 4f and g show an overview and depth profile of the entire route from Ilio Pt, Molokai to Honolulu Harbor. If DBEDT decides not to have an Ilio Pt landing, then the route would connect to the new segment and turn south toward Laau Pt. The depth profile did not change significantly from that of the original route into Pearl Harbor and indicates that the majority of this route is below 500m.

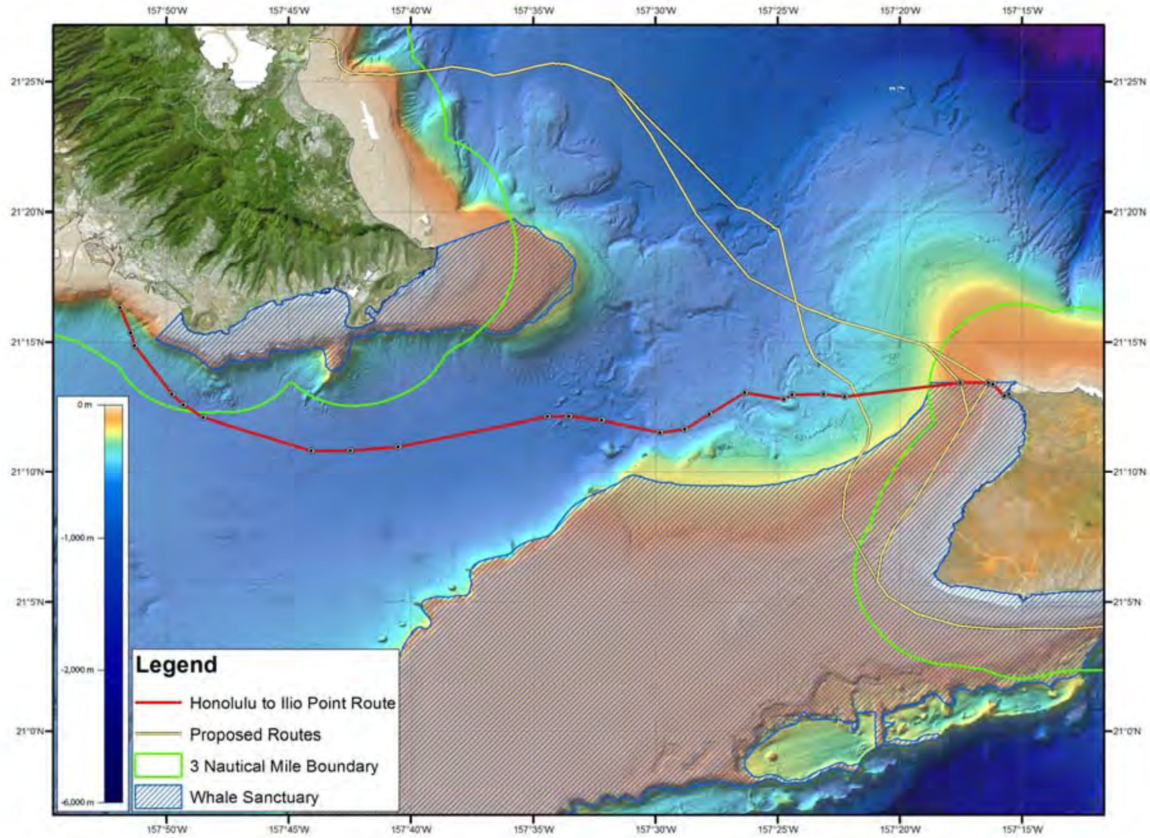


Fig 4f: Overview of the entire route between Ilio Pt, Molokai and Honolulu, Oahu.

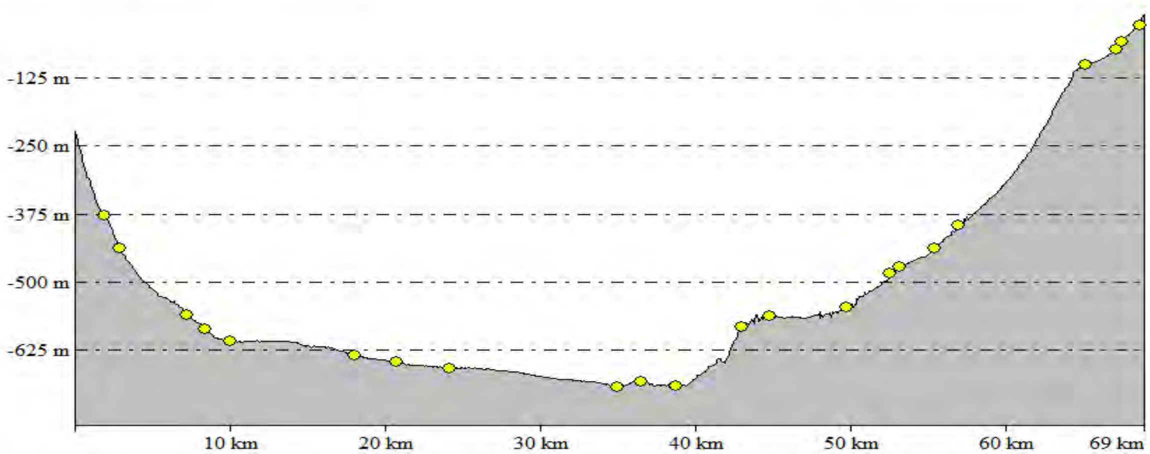


Fig 4g: Depth profile of the route between Ilio Pt, Molokai and Honolulu, Oahu

Discussion

The alternate route to Maui that remains within state waters south of Molokai clearly appears to be feasible but only if the cable can be "surface-laid" in at least two sections that are each over 2 miles in length. Relic reef structures are present in these areas that will prevent the cable from being buried. Furthermore, these areas are relatively shallow and a surface cable will likely be exposed to possible anchor damage from fishing or pleasure boats. The acceptability of this risk will have to be determined by DBEDT and its cable contractor.

An issue concerning the state 3 nautical mile boundaries came to our attention when this route was being developed. The currently recognized legal boundaries are shown on the NOAA nautical charts. However, a new 3 mile boundary has been created by Robert O'Connor of NOAA Fisheries based on more recent and updated shoreline data in the MHI. Since a petition to legalize these boundaries has been submitted, their acceptance is anticipated in the near future. Both DAR and DBEDT are currently distributing GIS shapefiles of these boundaries on their websites and therefore the O'Connor boundaries are what we have used in this report and show as the green lines in the figures. For this project, the difference between the two sets of boundaries is only a potential issue at the crucial point along the south coast of Molokai where the cable descends into the basin of Pailolo channel. The O'Connor boundary is closer to shore than the charted boundary so we recommended a route inside of the former that, regardless of which boundaries are in effect when the cable is installed, will remain in state waters.

The alternate route to Honolulu Harbor is more problematic due to the numerous obstacles, both physical and regulatory, that must be traversed in order to connect the cable to an Iwilei converter station. These obstacles are aggregated right at or near the harbor itself and as a result, we could not extend the route in this report further inland than the 230m contour. Additional information is clearly needed in order to determine whether a landing in or near the harbor is even a viable option.

Citations

Taylor, B. 2009. Hawaii "Inter-island cable ocean floor survey" Final Report, submitted to DBEDT November, 2009.

Taylor, B. 2010a. Hawaii "Inter-island cable ocean floor survey extension" Final Report submitted to DBEDT July, 2010.

Taylor, B. 2010b. Hawaii "Inter-island cable ocean floor survey extension 2" Final Report submitted to DBEDT August, 2010.