827



HDWC: OAHU-MAUI

# ANALYSIS OF SEAFLOOR SURVEYS, INC. PRECISION BOTTOM DATA BETWEEN MAUI AND OAHU IN DETERMINATION OF A POTENTIAL CABLE ROUTE

MAKAI OCEAN ENGINEERING, INC.

JULY 7, 1987

# HDWC: OAHU-MAUI
# DETERMINATION OF A POTENTIAL HDWC CABLE ROUTE BETWEEN MAUI AND OAHU

## OBJECTIVES OF STUDY

1. To review and analyze Seafloor Surveys, Inc. bathymetry data in determinating the feasibility of laying a cable from Maui to Oahu.

2. To identify an acceptable path if possible.

3. When applicable, identify the path width, obstacles on or near the path, and the required cable tension and bend radius requirements along a proposed cable route.

## APPROACH

Multiple survey passes along the proposed route (figure 1) were made by Seafloor Survey Incorporated in Cruise I, using the Sea-Marc II. Additional passes were made in a second SSI Cruise, covering incomplete and alternate areas, after the Cruise I data were analyzed (see Figure 2 for overall survey coverage). In addition to the acoustic digital bottom data recorded directly under the fish (Sea Marc II), bathymetry data to either side were collected and transformed into a color bathymetry matrix. An overall side-scan image was also available. The survey bathymetric and side scan image data were generally available at up to a 500m swath width (i.e. 250m to either side of the plotted survey tracks).

Approximately 170 km of terrain was surveyed covering a depth range from 60m to 750m deep. The data were made available in three different forms. These are, as previously mentioned, bottom profile data, color bathymetry plots and side scan images. These sources of data are discussed individually below. Appendix I provides a discussion of the data quality relative to the computer analysis.

### Bottom Profile Data

Bottom profile data were obtained from the acoustic transponder/receiver combination on the SeaMarc II. The first acoustic return was recorded as the bottom detect directly beneath the fish. Subsequent acoustic returns were noted at their associated angle of return in order to construct a bathymetry record up to 100m or more out to either side of the track.

### Color Bathymetry Plots

The matrix of bathymetric points obtained from the fish was transformed into a color bathymetry plot, each 5m depth increment represented by a shift in the color spectrum. This color contouring allowed more visual reference to actual bottom terrain and features. The color bathymetry provided an alternate image to the side scan - with the added benefit of depth graduations and the absence of distorted shadows.

### Side Scan Images

The third source of information was the side scan record. This was also used to identify major bottom features but is less quantitative than the contouring. The side scan image generally covered a swath width of 100m-500m, and was obtained with the fish 'flying' at an altitude of 50m-200m off the bottom, varying with water depth.

## DATA ANALYSIS (Bottom Roughness Impact on the Cable)

The best tracks in each area were selected for numerical analysis of bottom roughness, utilizing the bottom detect data from the transponder. The primary analytical tool used in determining bottom roughness was a computer program developed by Makai Ocean Engineering to simulate the bottom laid cable shape under a variety of tensions, for any given bottom terrain. This program predicts critical unacceptable bottom cable spans and bend radii along a given survey track for each possible cable bottom tension analyzed. This computer program was used extensively in the Alenuihaha survey data analysis and serves as an efficient tool for screening potential cable routes. Side scan and other data is then used to more closely examine particular areas in question. A more detailed description of this analytical tool is provided in Appendix II.

## RESULTS

In general, the terrain appears much smoother than that of the Alenuihaha Channel (Reference 1). A large percentage of the critical spans seen in this Oahu-Maui survey were in fact due to data noise (i.e. bottom detect errors). This is an indication of the sensitivity of the computer analysis to the quality of the bottom data.

Figure 3 shows the surveyed cable route and determined roughness based on the critical span analysis, color bathymetry and the side scan record. The majority of the original selected path is clear and smooth, except for the region off the SW coast of Maui and a few other isolated spots along the route. After analyzing the best available data from the two cruises, critical spans (unacceptably large predicted cable spans under a given tension - see Appendix II for details.) were located and those due to data errors were eliminated. The areas where critical spans remained were examined using the associated color bathymetry and side scan records. An attempt was then made to identify the nature of feature(s) causing critical spans. The location of these features are shown in figure 3, along an otherwise smooth path, as diamond-shaped symbols. There are eight areas which have been identified as potentially rough, and these areas are discussed in numerical order below:

1. A 1km long region of roughness was identified at the head of the steep slope off of Oahu's Makapuu Point. The data shows 5m-30m vertical 'peaks' in the bottom but these peaks are obviously not real, as the instruments are not capable of this resolution. The bottom is rough, and this causes bottom detect errors in the data. The associated side scan images also show an irregular bottom. Thus, this area in 150m to 200m depth is best avoided. A parallel track and its side scan image taken on the second SSI cruise shows a much smoother bottom along the 100m contour to the south, avoiding the steeper contours.

2. Survey and analysis of the deep channel (to 700m deep) SE of Oahu showed some rough areas in 650m to 700m of water at the bottom of the slope. The bottom profile shows 4-5m high oscillations along the bottom of unnaturally high frequency. Although no formidable obstacles show on the side scan, there is an uneveness to the surface which indicates some inherent roughness of the terrain. Side look bathymetry and side-scan results from nearby parallel tracks indicate that by passing slightly to the NE, we could avoid these rougher areas altogether.

3. Rising up from the channel towards Molokai, some roughness was observed at about 500m depth. The analysis highlighted an area of approximately 50m along a stretch of bottom. There is also some data signal dropout in the bottom profile data which indicates bottom detect difficulties. The side scan shows this region to be rough and iregular, but again shows that the area to the NE of these spans is relatively smooth and should be free of critical spans. This is also corroborated by an adjacent track to the NE which is indeed free of critical spans at all of the four tensions analyzed.

4. An isolated, relatively shallow 6m rise near the SW coast of Molokai is seen and critical spans are indicated at the higher tensions. This rise is easily passed over at the lower tensions, and the side scan image indicates that this area is reasonably smooth also. The depth is only 50-100m, which easily permits laying the cable at low tension.

5. North of Lanai, there are two rough spots indicated. These two areas coincide with a rise and fall of a 25m high shelf crossing this location. The analysis produced critical spans at the two higher tensions of 2000 kg and 3000 kg. This feature may be avoided by a circuitous route but is more easily passed over by laying the cable at 1000 kg tension or less, the latter being the recommended choice. The depth is 200m.

6. There is a rough area, in 50-70m of water to the East of Lanai and detected in four separate survey tracks. This area is characterized by a number of outcrops between 5m and 15m in height. They do not appear to be very steep, although close examination of bottom profile data and side scan records indicate the likelihood of bottom detect errors triggered by a rough bottom. There is no evidence in the side scan of any particularly formidable obstacle, or of any sharp ledges. This region does contain a number of smaller rises, which are best dealt with by laying the cable at 1000 kg, and at high accuracy to steer a course around the more formidable features. Both of these options are easily manageable in the shallow waters in this region.

7. This spot highlights a large outcrop to the South of the survey tracks. Although no track crosses this obstacle, and no spans are seen as a result, this obstacle is clearly evident on side scan and should be avoided.

7./8. This area along Maui's SW coast is characterized in the side scan record as being full of outcrops and patch reef. The deeper tracks showed a great deal of roughness due to the abundance of outcrops. On the second cruise, it was decided to survey the shallower waters for a smoother cable route. This area proved to be considerably smoother, but not without a few rough spots that would cause problems at the higher cable tensions. The cable lay should thus be made at a relatively low tension (1000 kg or less) in this area. The cable lay should also be laid with high accuracy in this area, attempting to avoid the larger reef formations and outcrops. Again, this is easily manageable in this shallow water in this area.

Figure 4 shows the current recommended cable route between Oahu and Maui. The path width is generally 400m over nearly all of this route, as shown to be generally clear in the side scan record. The cable lay tension can be as high as 3000 kg over most of the route, except in isolated rough areas where it should be reduced to 1000 kg. This includes all of the areas tentatively identified as rough, until more information becomes available.

## CONCLUSIONS AND RECOMMENDATIONS

The path has been characterized as being smooth over approximately 95% of the route. Isolated spots have been characterized as rough enough to warrant going around them or laying over them at a reduced tension. The path is not restricted in width except to the extent of our side scan swath, which is 500m wide over most of the surveyed path. All obstacles on or near the path have been highlighted, and accommodations to the cable route have been recommended by laying under lower tension and/or avoiding the rough areas/obstacles. The required cable lay radius along the proposed HDWC cable route is not restrictive. Although the selected route makes some tight turns, the bottom near these turns is relatively smooth.

The cable could be laid at 3000 kg tension over the majority of the route. In isolated rough areas, the tension should be reduced to 1000 kg to prevent critical spans over potentially rough terrain.

Although a "final" cable path has not been identified for a few isolated locations, the survey has illustrated that locating the final commercial route will not be difficult and that the cable laying process will not be hindered because of cable path restrictions.

## REFERENCES

Hawaii Deep Water Cable Program, Second Bottom Roughness Survey of the Alenuihaha Channel, January, 1987. Makai Ocean Engineering and Scripps Institute of Oceanography

# APPENDIX I

## DISCUSSION OF DATA QUALITY

The off-track bottom profile data were determined to be less suitable for analysis in comparison to bottom detect data (directly beneath the fish track) due to the compound effects of bottom detect errors, data noise and fish roll. Bottom detect data were analyzed but also contained a fair number of spikes due to bottom detect errors (early bottom detect or loss of signal). This caused the computer analysis to compute many non-real, unacceptably large spans in the numerical analysis, and subsequently required some post-processing using reference side scan and color bathymetry.

Color bathymetry plots were used to supplement the cable span analysis, in identifying major features along the bottom, and also proved very convenient to verify data errors as well. A data error (or 'spike') could usually be identified as a loss of bottom detect signal (shown as a white pixel) or an early bottom detect (single pixel color shift) in the color bathymetry matrix. If the 'spike' were real, the color bathymetry would corroborate this by showing the extent of the feature over more than one pixel leading to larger span(s).

The side scan provided a good overall image of the area to identify major bottom features. The field of view was quite large but could not identify the height and composition of specific features which were likely to cause critical spans.

# APPENDIX II

## BOTTOM ROUGHNESS ANALYSIS PROGRAM

A measure of impact of bottom roughness on the Hawaii Deep Water Cable is determined by analytically laying a cable over the measured profiles and computing the lengths of the resultant free spans and the associated bend radii. Because of the very large quantity of data gathered for determining the bottom roughness and because only the more elevated data points affect the cable shape and spans, the cable program makes successive approximations of spans before utilizing a detailed analytic cable solution.

The first approximation can be visualized as rolling a ball along the bottom roughness data. The first approximation of cable contact points is made when the ball contacts two data points. The ball is 'rolled' one more step to get an approximation for the next span, which is used in determining an approximate end condition for the current one. A more exact solution for the span is then calculated, knowing the span length and the approximate cable angle at each of the contact points. This more exact solution is compared to the bottom bathymetry between the contact points to ensure that it is indeed a valid cable span. If not, new intermediate contact points are determined and the process is repeated. Once a clear span is determined, the bend radius at either end of the span is also computed. If the span is of excessive length, as determined by Pirelli's criteria for critical span length as a function of the laying tension, it is tabulated as an unacceptable or critical span. If the bend radius is less than 1.5 m, it is also tabulated as an unacceptable span for reasons of bend radii.

This analysis gives an estimation of cable touchdown points and subsequently, spans and bend radii, based primarily on Love's equation (Love, Treatise on the Mathematical Theory of Elasticity, Dover 1927). This method, although complex, is only an approximate solution to the differential equations modeling a laid cable.

### UNACCEPTABLE SPANS AND BEND RADII

Each of the tracks that had potential for a cable route were processed to determine the extent of unacceptable cable spans and bend radii, if a cable were to be laid down that path. By this means and by plotting the location of the unacceptable spans both in the plan and profile views, the roughness was evaluated and patterns, if they exist, could be determined.

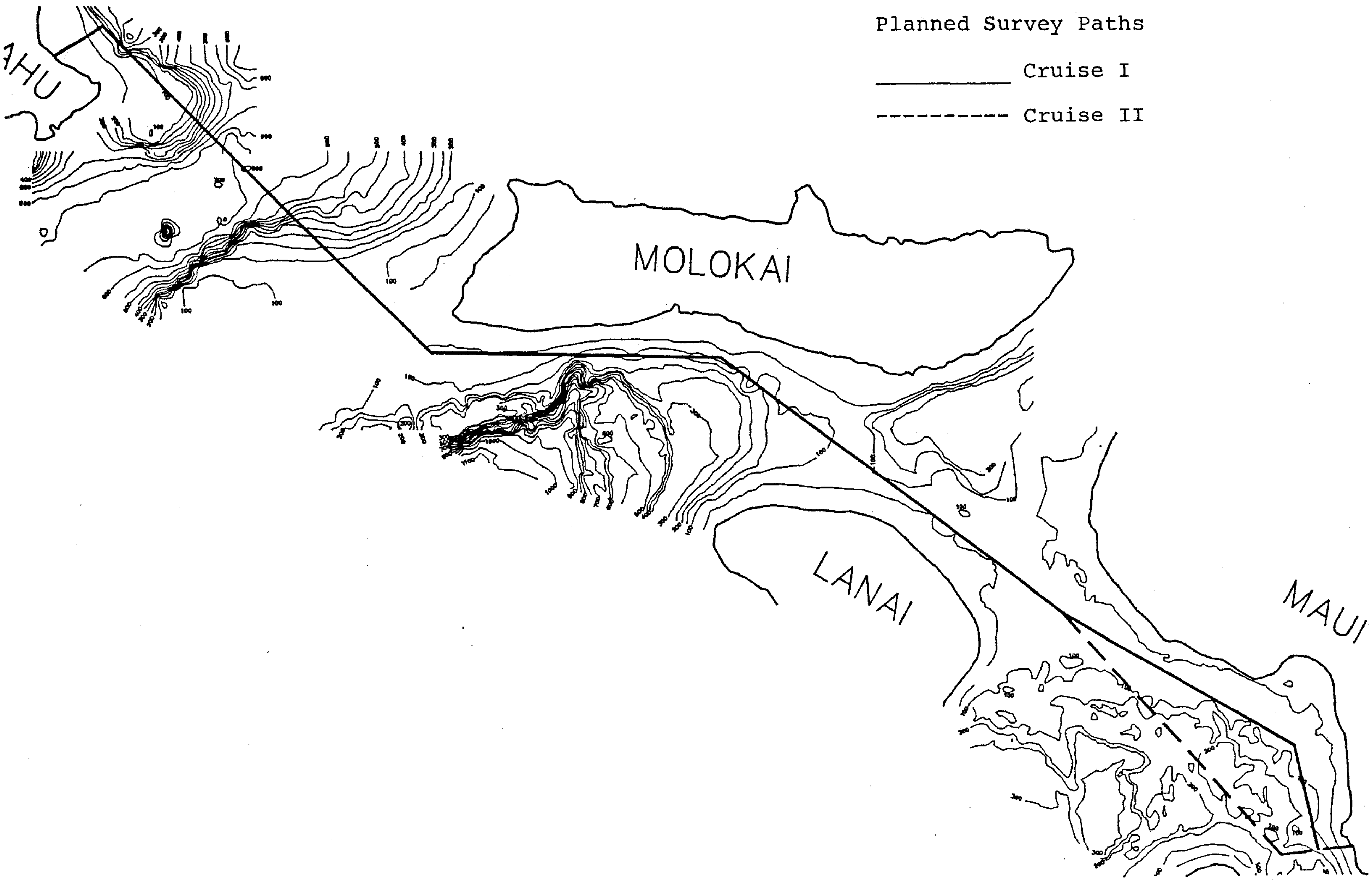
The critical bend radius, to prevent cable kinking, is noted to be 1.5 meters, independent of tension. The critical cable span, being a product of dynamic fatigue analysis, is strongly a function of bottom tension and cable properties, and ranges from 20 meters to 60 meters for the tensions up to 5000 kg.

Figure 1

Planned Survey Paths

________ Cruise I

---------- Cruise II



## Figure 2

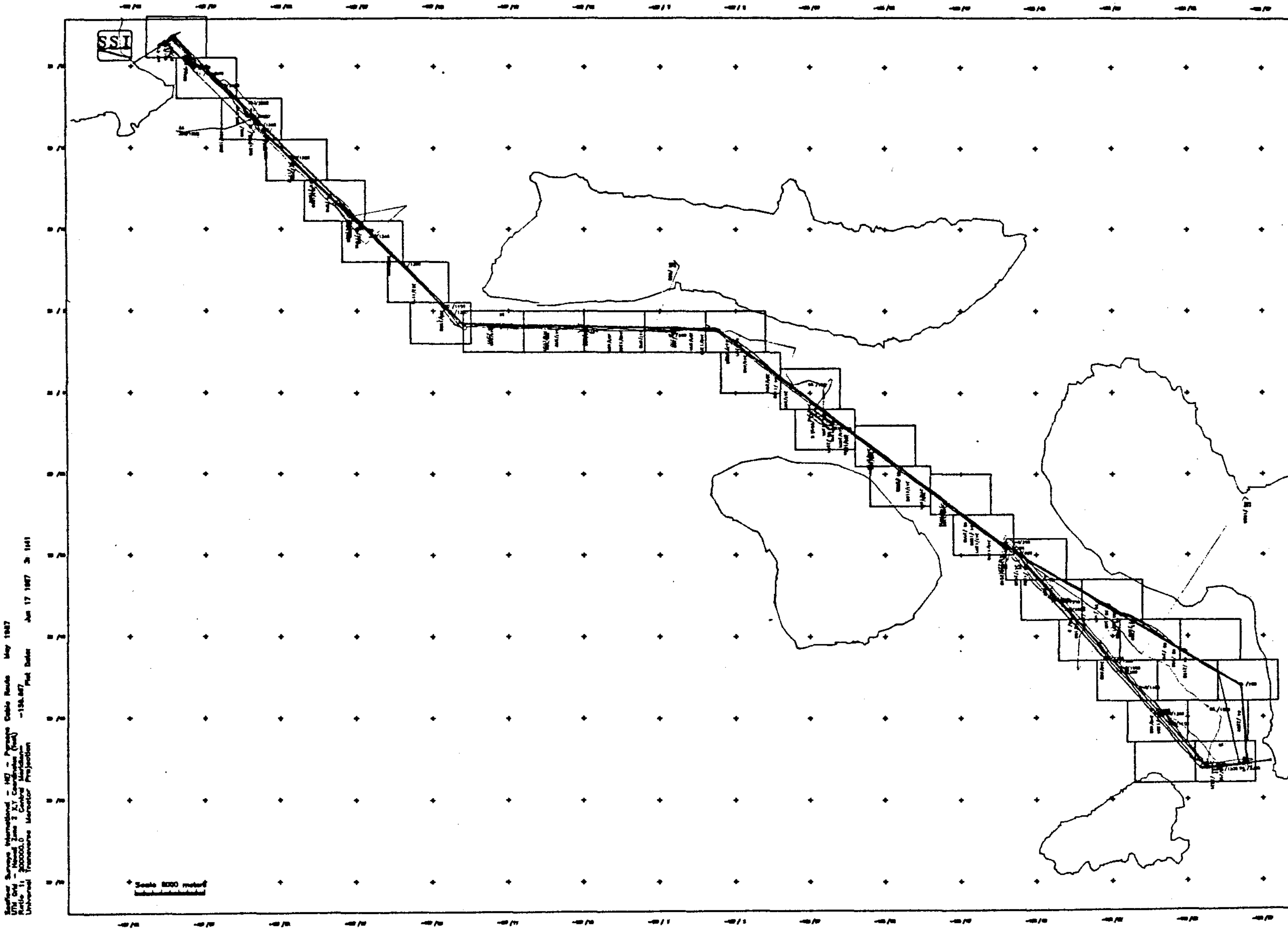


Figure 3

Bottom Roughness Along Proposed
Oahu-Maui HDWC Cable Route

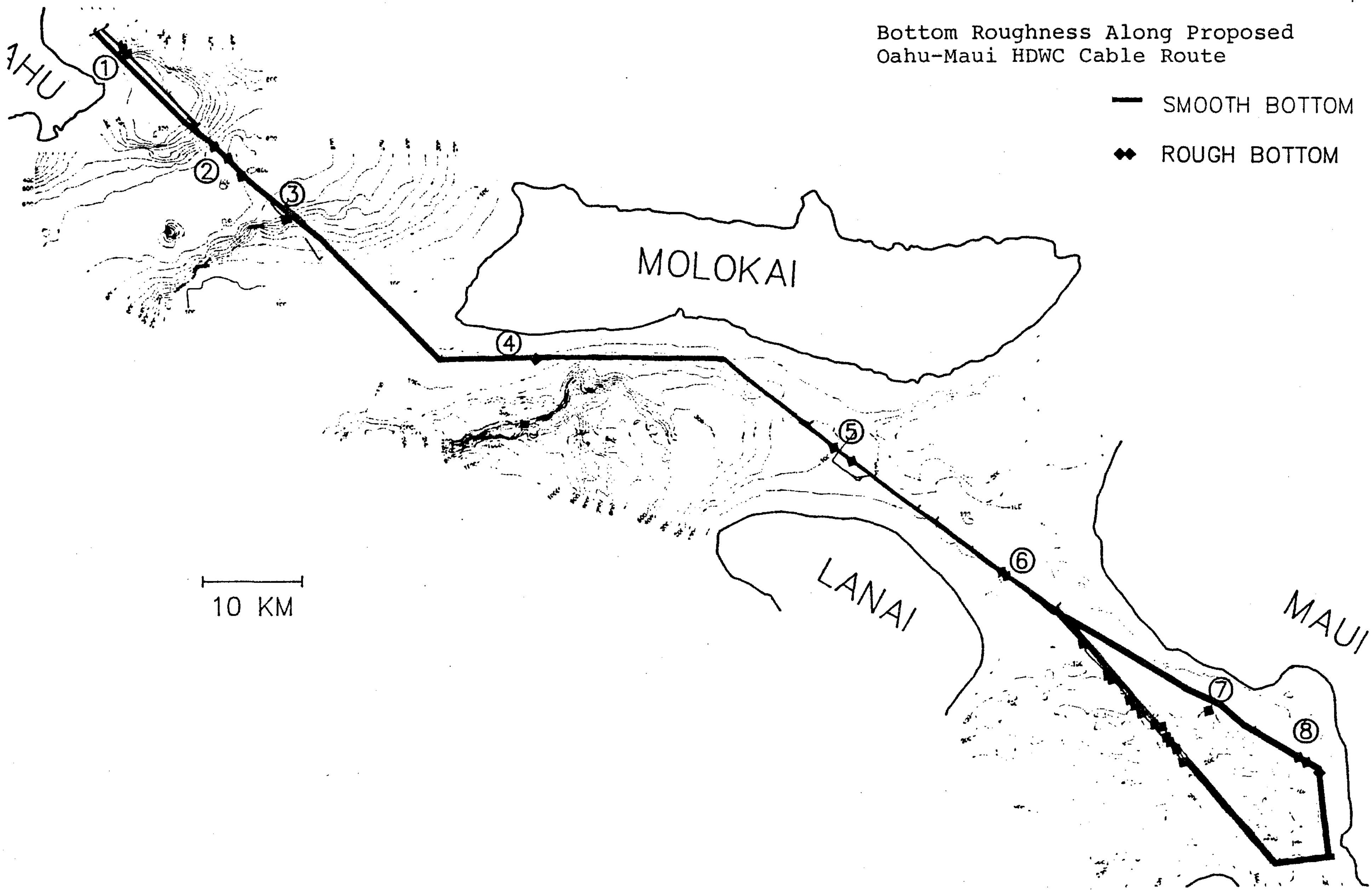


Figure 4

Recommended HDWC Cable Route
Oahu-Maui