Seafloor Texture Analysis of Saipan Anchorage Bathymetry using Local Fourier Histogram (LFH) Texture Features: LFH class maps from Saipan bathymetry using unsupervised classification and supervised classification based upon seafloor video image data.

Draft Final Report

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October 2004

Submitted to:

NMFS Pacific Islands Fisheries Center,

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Order number JJ133F04SE0124

Requisition/Ref. No. NFFR7400-4-00124

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Abstract

For some parts of the seafloor, morphological characteristics can be used to distinguish benthic habitats. The purpose of this work was to segment and classify the seafloor according to apparent and identified benthic habitats using morphological textures in multibeam echosounder bathymetric data from a study area off the island of Saipan. Unsupervised classifications provided reasonable segmentation and apparently accurate representation of the spatial distributions of most prominent morphological features. However, detailed interpretation of those results were difficult, and apparent misclassifications required arbitrary adjustment of some aspect of the classification procedure, confounding attempts of optimization. Three supervised classifications were done by assembling training sample texture feature prototypes from (1) randomly selected set of points, (2) video image positions, and (3) video, random, and arbitrary points combined. The random classification using many (100) points was very good at separating out many feature types, however with so many samples, not all could be assigned a class type or name. Using fewer random samples (10) allowed interpretation of seafloor class or type to some extent from the bathymetry, however not all apparent habitats were represented when few training samples were used. Classification using LFH prototypes generated at positions where video ground-truth data existed allowed direct use of ground-truth data for classification of all bathymetric grid cells. However, as with the random samples, not all habitat types were represented. Using the set including all LFH prototypes from random, video ground-truth, and arbitrary samples allowed classification according to all of the prototype classes, resulting in a classified map considered to represent a more reliable hypothetical habitat map for most of the study area. Additional ground-truth data and interpretation would be beneficial for

testing the validity and accuracy of the hypothetical habitat maps from each of the classification strategies.

Introduction

The benthic habitat mapping mission for the Saipan anchorage study area, Northern Mariana Islands included texture analysis of bathymetry grid data in order to segment and classify the seafloor according to morphology. Texture analysis has been applied in several studies recently to acoustic backscatter data from multibeam echosounders or sidescan sonars (Huvenne, et al., 2002; Canepa and Pace, 2000; Canepa, et al., 2002). In addition, texture analysis has been applied to bathymetric data to generate predictive benthic habitat maps. Because of the quality and coverage and resolution of bathymetric data now available from multibeam echosounder systems in shallow water, Cutter, et al. (2003) were able to successfully segment seafloor facies and apparent benthic habitat types by applying texture analysis to bathymetric data from a shallow water survey. Cutter, et al. (2003) used a modified form of a texture feature called the Local Fourier Histogram (LFH) that had been developed by Zhou, et al. (2001) for grayscale image texture classification and discrimination. The LFH texture feature technique has been shown to classify textures as well or better than co-occurrence matrices, and have nearly the same texture recognition rate as Gabor features, however LFH features are less demanding, computationally (Zhou, et al., 2001). Cutter, et al (2003) modified the LFH technique by varying the spatial scales of the analysis. A similar approach is used in this study, however the spatial scale variation for the analysis was accomplished by using multiple grid resolutions.

This study involved LFH texture feature analysis of gridded bathymetric data from a Reson 8101ER multibeam sonar dataset collected in the waters of Saipan, in an area where naval anchorages exist. LFH analysis of bathymetry is part of the process of segmentation and delineation of benthic and coral reef habitats in the Saipan anchorage area. The LFH analysis differentiates local morphological textures. A primary consideration requiring testing and ground truth data is whether the morphological textures distinguished represent distinct coral species, or morphotypes, or benthic substrate configurations related to substrate type classes.

Segmentations and classification maps were generated using unsupervised and supervised classification techniques. The initial stage involved using unsupervised classification of LFH texture features using k-means cluster analysis of LFH data from arbitrary grid cell blocks sizes and arbitrary number of cluster groups. After reviewing those preliminary segmentation maps against the digital terrain models (DTM's) and video ground-truth data, the strategy was modified such that training point sample locations would be used to develop representative, or prototypic, texture features for use in supervised classification scheme. Three approaches were implemented for supervised classification. Each involved a different method of selecting training point locations and whether there existed ground-truth data to suggest what the class represented. The supervised classifications were done by assembling training sample texture feature prototypes from (1) randomly selected set of locations, (2) video image data locations, and (3) a set of training samples including video, random, and arbitrary sample locations. Each approach to segmentation and classification provided reasonably good results, but each was dependent upon the number of, locations of, and positioning uncertainty associated with the training samples used.

LFH classification using the video ground-truth training samples should be the most robust method of seafloor characterization and description of benthic habitats in the study area, except that positioning uncertainty of the ground-truth data can lead to LFH class prototypes being generated at the wrong location, and not all seafloor feature types were sampled by the video. In those cases, the LFH prototype can incorporate data that does not belong to a particular morphological texture class. Because many ground-truth data observations were available and mean LFH vectors were used, it is assumed that positioning error effects would not influence the overall form of the LFH prototypes. Using only the video ground-truth data for generation of LFH class prototypes also means that either all data are assigned to one of those classes, or another class representing "other" categories must be allowed. That was the origin of the "zero" class and the combined approach. By allowing for an "other" or "background" class, we are effectively saying that our set of prototypes does not represent all possible forms of feature vectors we will encounter. An "other" or "background" class is intended to apply to all observed data that do not fit our prototype classes. However, it was assumed that observations found to belong to none of the prototype classes were therefore part of the "other" class. It was apparent from the bathymetric map that there were likely to be several distinct morphological classes that would be classified as "other," thus that the "other" class would actually represent multiple undescribed classes. A strategy to allow for multiple additional classes that would be a refinement of the "other" class was imposed. This involved developing prototype classes from random and arbitrary training sample locations which would be used in conjunction with the video ground-truth LFH prototypes. The final classification is a result of the combined approach where each cell in the 5 m grid cell size map was classified according to the set of video, random, and arbitrary LFH prototypes.

The combined approach utilized class prototypes developed from training samples from ground-truth video data, randomly selected locations, as well as arbitrarily selected locations.

The combined approach improved the overall segmentation of the seafloor into distinct textures and apparent habitats, however not all could be assigned class, or habitat type, names without additional ground-truth data. Using all the LFH prototypes generated from random, video ground-truth, and arbitrary samples allowed classification according to all of the prototype classes. The resultant classified map from combined training origin classification was considered to better represent the actual distribution of seafloor morphologies and benthic habitats in the study area.

Datasets and Methods

Bathymetric data grids from Saipan

Bathymetric grids were generated from Reson Seabat 8101ER multibeam echosounder data at several grid cell resolutions by University of Hawaii, Hawaii Mapping Research Group (HMRG). Initial tests for segmentations and classifications were done using 4 m, 5 m, and 10 m grids. Later, testing was done using 1 m and 3 m grids. It was decided that 5 m grids were to be a standard product, and that 1 m grids would not be a reasonable product to expect generally because of water depth ranges and storage space constraints. The 5 m grid cell map was regridded at 10 m and 20 m to explore the effects of map resolution on results of texture feature segmentation and classification. The 5 m grid was used for supervised classifications and final map products.

Seafloor video analysis data

Data from the analysis of seafloor video imagery collected from a towed camera sled was provided by Dr. John Rooney. Data from eleven video camera tows acquired in 2003 were used as ground-truth for the bathymetric data. Each video sequence was analyzed at 30 second intervals, providing from 18 to 96 samples per tow (Table 1).

Table 1. Number of analyzed frames (N) by video tow.

TOW	N
103	24
104	31
105	21
106	35
108	34

Table 1. Number of analyzed frames (N) by video tow.	
109	27
110	96
111	33
112	18
113	26
114	27

The video data were reviewed and levels (categorization names) of variables were made consistent. Classification using mean LFH vectors from video locations were done according to the video data variable (SUBSTR) describing substrate. There were seven levels, or categories, of substrate: CaCO3 Boulders; CaCO3 Rock; CaCO3 Rock and Sand; CaCO3 Rubble; CaCO3 Rubble and Sand; Sand; Sand and CaCO3 Rock. Those categories of the variable substrate from the video data were used to generate training sample LFH class data. The variable "Structure" was considered, but “Substrate” was correlated with "Structure." “Substrate” was chosen because it contained two categories ("CaCO3 Rubble" and "CaCO3 Rock") that separated and distinguished the “Structure” category "Mound." For every spatial position where a category of video substrate was identified, a LFH feature vector was calculated. Using all of the individual LFH feature vectors from each substrate category, a mean LFH feature vector was calculated for each substrate category and used as LFHvgt class prototypes (LFHvgt stands for LFH video ground-truth). Table 2 summarizes the number of samples for each video substrate category. Three of the substrate categories represented mixed substrates, and that could impact classification results.

Table 2. Levels of the video data variable describing substrate (SUBSTR).

Level	Count
CaCO3 Boulders	5
CaCO3 Rock	79
CaCO3 Rock; Sand	20
CaCO3 Rubble	61
CaCO3 Rubble; Sand	6
Sand	178
Sand; CaCO3 Rock	23

The goal was to develop LFH prototype classes for video data classes that might have some textural expression in the bathymetry dataset. It was determined from reviewing the video data on the DTM that the "Structure" levels observed from video appeared associated with features observed in the 5 m DTM, at least. Some "Structure" level objects did not appear to have very distinct feature-for-feature expression in the 5 m grid DTM, therefore 3 m and 1 m grid DTM's were generated to see if carbonate structures such as coral heads might be observed directly in the DTM. In places where coral was identified in the video data, the 1 m DTM seemed to have roughness patterns that were similar to the coral structures. However, the evidence was not strong enough to support extensive analysis of the 1 m grid for this study.

LFH analysis and classification

Initial, unsupervised classification LFH analysis was applied to the Saipan bathymetry data gridded at three resolutions: 5 m, 10 m, and 20 m grid cell sizes. LFH texture features were produced using the method described by Zhou, et al. (2001). Multiple spatial scale analysis was done here using several grid resolutions, a modification of the technique used by Cutter, et al. (2003) where various ranges were used within a single dataset (multiple ranges surrounding a single cell of a single resolution grid).

LFH texture feature construction

A summary of the LFH analysis technique is provided here. Each non-edge grid cell has eight nearest neighborhood grid cells. The depth values of those eight cells are treated as a sequential data series (z(0), ... z(7), where the first element z(0) was the top center cell that could be considered oriented northward of the central grid cell). The mean value of the neighborhood series was removed to prevent depth from influencing the analysis and classification. Then, a discrete Fourier transform (DFT) is applied to the data series. Applying the DFT to the local neighbors led to the texture feature name, "local Fourier," described by Zhou, et al (2001). The DFT of the eight-element series z(n), where $0 \leq n \leq 7$, produces eight Fourier transform coefficients, F(k):

$$F(k) = (1/N)*\sum z_n \exp(j(\pi/4)nk) \qquad 0 \leq k \leq 7$$

(Zhou, et al., 2001). The template method of Yu, et al. (2002) was used to extract the local Fourier coefficients. Coefficients zero through three (F(0), F(1), F(2),F(3)) were used to construct the LFH texture feature for each block of grid cells. F(0) represents the zeroth component or average value, F(1), F(2), and F(3) represent the 1st, 2nd, and 3rd harmonic frequencies: 1/T, 2/T, and 3/T, where T is the sampling period or series length in real units. If we make the assumption that the series represents a revolution around the central cell, and that grid cell sizes represent sample intervals, we have a series of 8*(grid cell size). For example, for the 5 m grid cell size map, the neighborhood series represents T = 8*5 = 40 m. Therefore, F(1), F(2), and F(3) represent waveforms with (spatial) frequencies of 1, 2, and 3 cycles per 40 m, or spatial wavelengths of approximately 40 m for F(1), 20 m for F(2), and 13.3 m for F(3). These are provided as general guidelines for understanding the methodology, and should not be used for interpretation of the LFH feature vectors in strict physical sense because the sampling period does not necessarily express exactly the fundamental frequency (1/T) of the phenomenon.

Since F(k) are calculated for the neighbors surrounding each cell in the data grid, the values for F(k) are assigned to the central pixel. Therefore, the first products of the analysis are four Local Fourier coefficient maps (LFM's) that represent the values of F(k). Histograms are produced for the quantized (into eight bins) values of F(k) within blocks of grid cells. The size of grid cell blocks was arbitrary, and this study used 10 by 10 grid cell blocks. The Local Fourier Histogram (LFH) texture feature is generated by concatenating the histograms from each F(k). LFH texture features representing each block of grid cells, and assigned to the central cell location.

Unsupervised Classification

Unsupervised classification was done using cluster analysis (k-means clustering) and an arbitrary number of (10) cluster groups. LFH feature vectors from ten cell interval centers (ten by ten cell blocksize) were assigned to one of the ten cluster groups according to k-means clustering using FuzMe (Minasny and McBratney, 2000).

Supervised Classification

Supervised classification was done using LFH texture feature vectors from random and arbitrary training sample positions, and using mean LFH generated at estimated positions of video ground-truth image data. Supervised classification results are provided for the 5 m grid cell size bathymetric grid from Saipan. Class membership for each map grid cell were assigned using a minimum-distance classifier criterion. Two distance measures were tested: the Euclidean distance (L-2 norm) and the chi-squared statistic. There were no differences detectable in the results from either. The chi-squared statistic was used for final supervised classification maps because it has been shown to outperform, albeit only slightly, the Euclidean distance for texture image retrieval accuracy and efficiency (Zhang and Lu, 2003). A chi-squared statistical test was not applied, rather the class membership was assigned according to the minimum chi-squared statistic calculated for the unclassified cell LFH data (observed) and the training sample or prototype data (expected). Single prototypes (see Tau and Gonzalez, 1974) were used for the training sample classes, requiring the assumption that the mean LFH for each prototype classes sufficiently represented that class, and that the spread or variation of prototypes within a particular class was relatively low. The chi-squared statistic was calculated as:

ChiSquaredStat = Sum((Observed-Expected)^2/Expected)

over all bins, LFH(0)-LFH(31).

Supervised classifications were done using random, arbitrary, and video ground-truthing training samples. LFH class prototypes were developed for random locations, arbitrary locations for which morphological characteristics were identifiable, and for video image analysis data. Then, all map grid cells were classified using the minimum distance classifier strategy, wherein the class applied to the grid cell was the prototype class for which the minimum chi-squared statistic distance existed.

The geographic positions for the 10 and 100 random samples used to develop LFH prototypes are listed in the Appendix. The video ground-truth position data and interpretive data are listed in the Appendix. For each level of the video data variable “SUBSTR” representing substrate type, a mean LFH feature vector was calculated and used as the LFHvgt prototype. The arbitrary classes and position data where they occurred are listed in the Appendix.

Map products

Maps were generated from several steps of the LFH analysis process. These maps include Local Fourier Magnitude (LFM) maps depicting each of the Fourier coefficients used to construct the LFH texture features, a “LFMRGB” (that is also being called “psuedospectral”) map depicting a simultaneous combination of Local Fourier coefficients. The psuedospectral LFMRGB map has red, green, and blue (RGB) color values weighted by the values of F(1), F(2), and F(3). Finally, there are maps showing LFH texture feature classes from unsupervised and supervised classifications. Unsupervised classes represent a k-means cluster grouping where the LFH texture feature dataset was separated into ten cluster analysis classes. LFH maps from supervised classification with class names applied from video ground-truth data were generated from comparison of all LFH data to mean LFH vectors generated according to training samples.

Results

Bathymetric grid

Bathymetric map with 5 m grid cell, color coded depths

The gridded bathymetric data from Saipan used for LFH classification had a grid cell size of 5 m, and approximate dimensions of (E) 11910 by (N) 14590 by (z) 297 m (Figure 1).

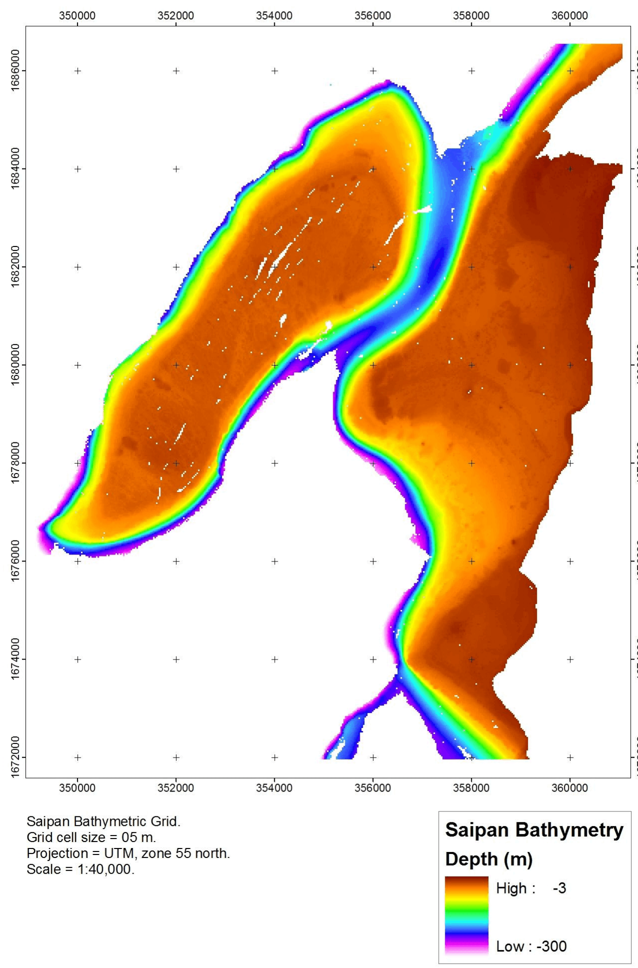

Figure 1. Saipan bathymetric data grid, with grid cell size of 5 m, color-coded depths. Coordinates shown are Eastings and Northings (meters) of Universal Transverse Mercator (UTM) projection zone 55.

Bathymetric map with 5 m grid cell, shaded surface

Depicting the bathymetric grid as a shaded surface (Figure 2) reveals some of the gross morphological attributes such as a deep central channel, bordered by shoal regions with what appear to be a variety of reefs and sedimented areas.

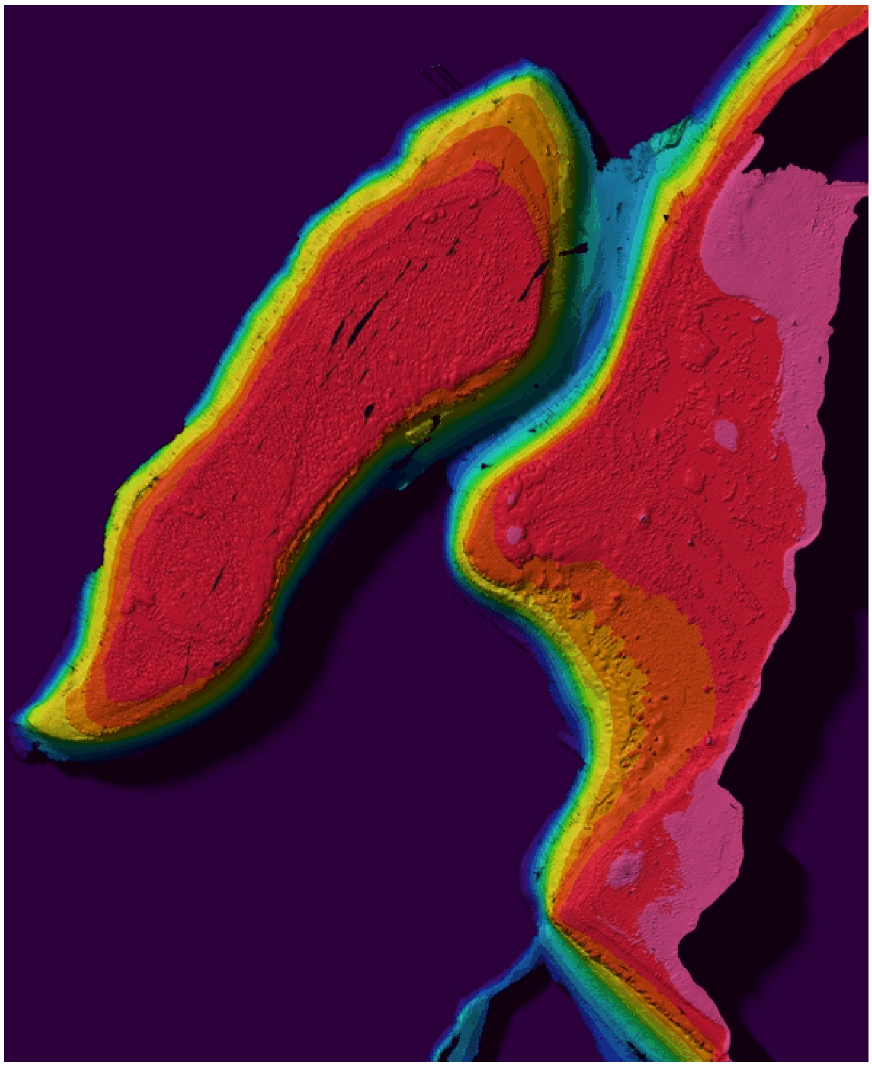

Figure 2. Saipan bathymetric data grid, with grid cell size of 5 m, shaded surface.

LFM maps from three grid cell sizes

5 m grid cell LFM maps

The LFM maps from the 5 m grid (Figure 3) that formed the basis for the LFH analyses and classifications, were color-coded such that red, green, and blue were assigned to F(1), F(2), and F(3). Higher intensities represent larger values of those three components.

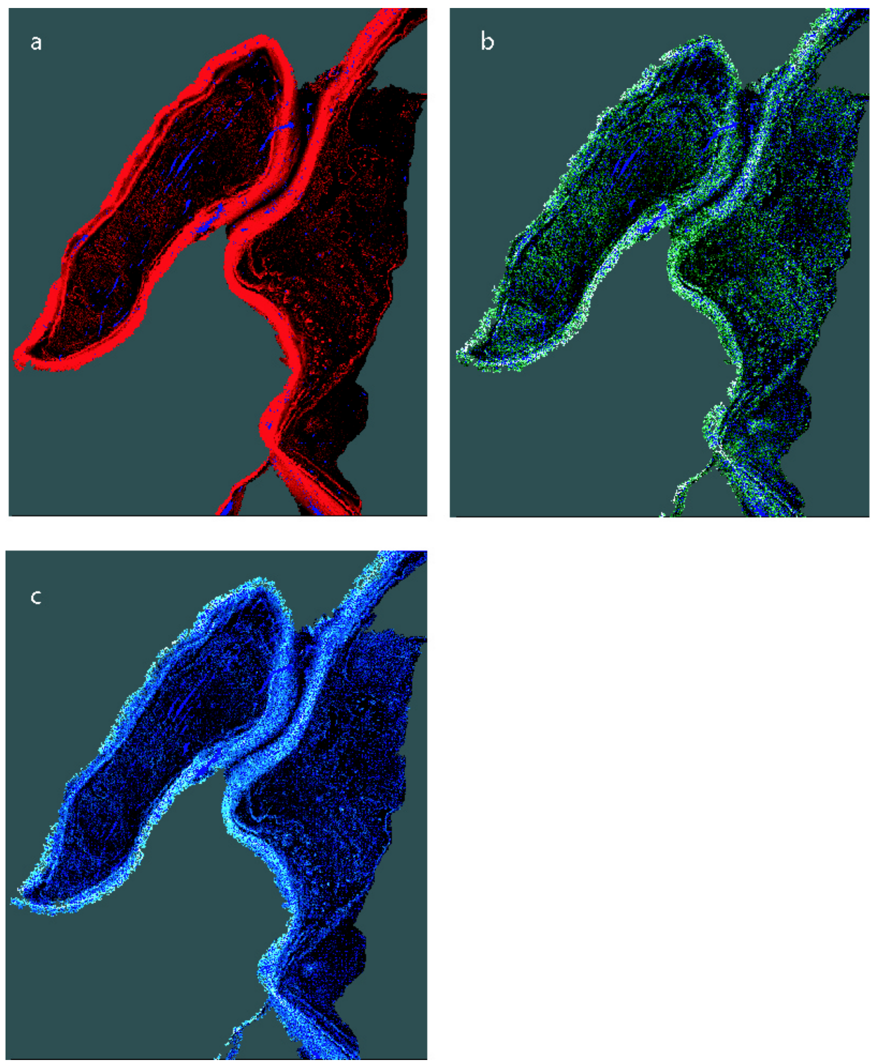

Figure 3. LFM maps for the 5 m grid cell size bathymetric data from Saipan. a) LFM1, b) LFM2, c) LFM3.

10 m grid cell LFM maps

The LFM maps from the 10 m grid (Figure 4) were color-coded such that red, green, and blue were assigned to F(1), F(2), and F(3).

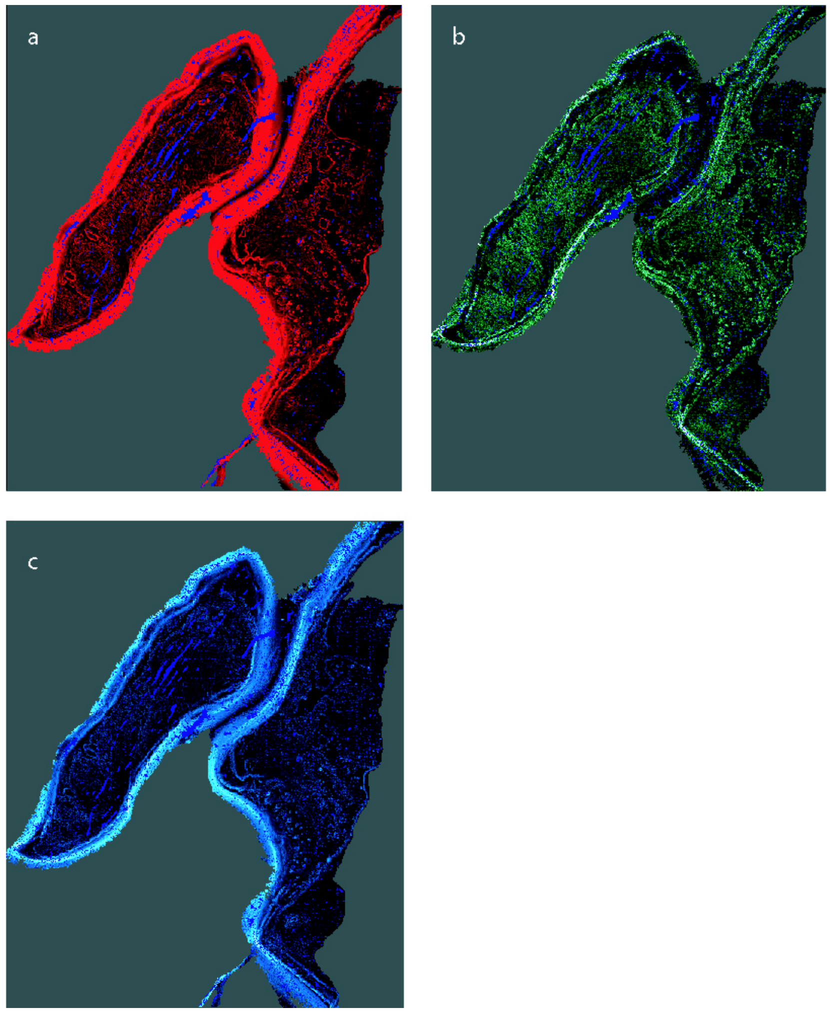

Figure 4. LFM maps from 10 m grid cell size Saipan bathymetric data. a) LFM1, b) LFM2, c) LFM3.

20 m grid cell LFM maps

The LFM maps from the 20 m grid (Figure 4) were color-coded such that red, green, and blue were assigned to F(1), F(2), and F(3).

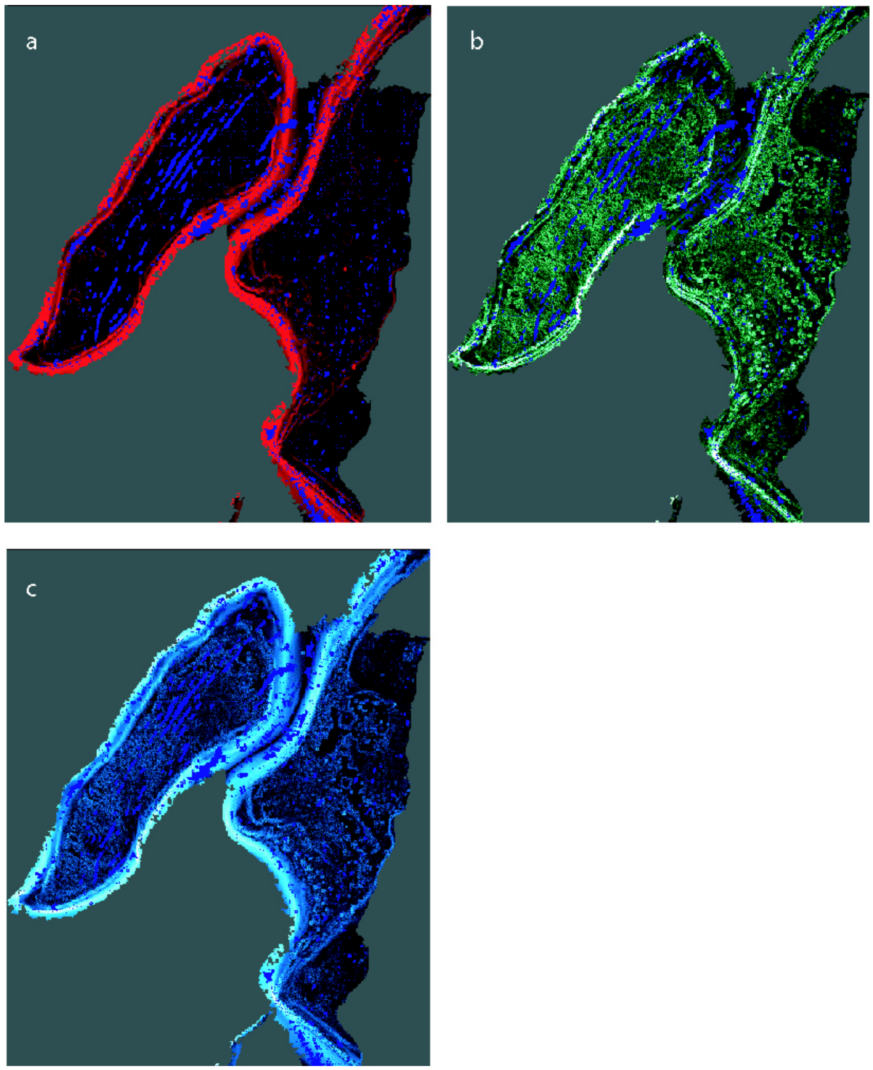

Figure 5. LFM maps from 20 m grid cell size Saipan bathymetric data. a) LFM1, b) LFM2, c) LFM3.

Pseudospectral (LFMRGB) maps from three grid cell sizes

By combining the individual weighted and colorized LFM maps, we develop what we call a psuedospectral, or LFMRGB, map for each grid cell size map analyzed (Figures 6, 7, and 8). Using intensity and color, the psuedospectral LFMRGB maps convey multiple spatial scale roughness of the seafloor, where smooth seafloor is represented by black or low intensities, low spatial frequency variation in the bathymetry is represented by red, intermediate spatial frequency variation in bathymetry is represented by green, and high spatial frequency variation in bathymetry is represented by blue. These can be interpreted to some extent as: where a pure color indicates dominance of one spatial frequency roughness component, and combinations of colors as representing the simultaneous occurrence of combinations of spatial frequency roughness features. However, because the DFT represents a sample series and not the fundamental waveform, and because the data are a regular grid meant to represent the seafloor shape at a particular resolution, these should not be interpreted in strict physical sense.

5 m grid cell LFMRGB map

Figure 6. Pseudospectral LFMRGB map for Saipan bathymetry grid with 5 m cellsize. Red Green and Blue image color band values represent weighted values of local Fourier coefficients 1, 2, and 3 (F(1), F(2), F(3)), which represent variation at a range of spatial frequencies relatively low, medium, and high.

10 m grid cell LFMRGB map

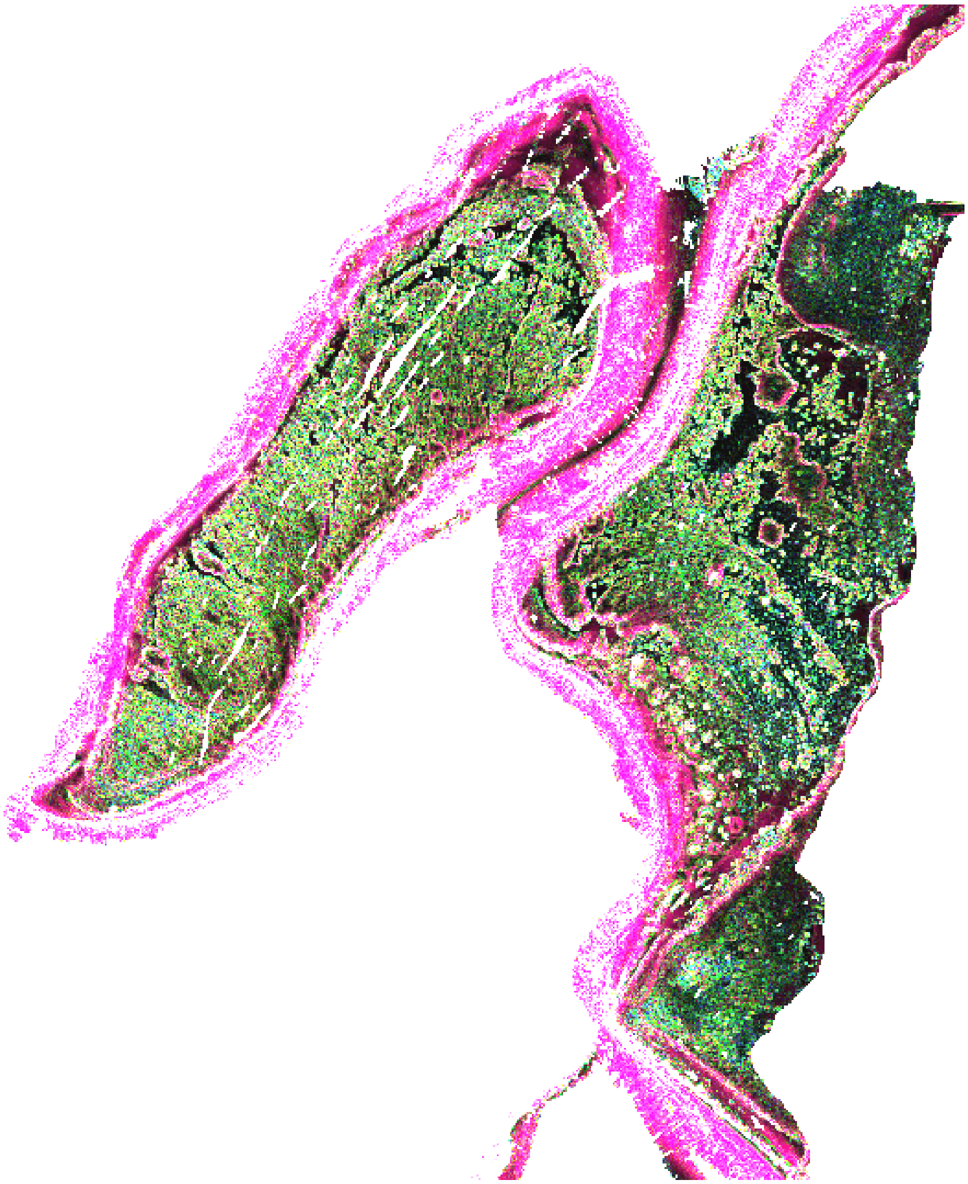

Figure 7. Pseudospectral LFMRGB map for Saipan bathymetry grid with 10 m cellsize. Red Green and Blue image color band values represent weighted values of local Fourier coefficients 1, 2, and 3 (F(1), F(2), F(3)), which represent variation at a range of spatial frequencies relatively low, medium, and high.

20 m grid cell LFMRGB map

Figure 8. Pseudospectral LFMRGB map for Saipan bathymetry grid with 20 m cellsize. Red Green and Blue image color band values represent weighted values of local Fourier coefficients 1, 2, and 3 (F(1), F(2), F(3)), which represent variation at a range of spatial frequencies relatively low, medium, and high.

LFH maps from unsupervised classification

The initial classifications of the Saipan bathymetric data gridded at three resolutions (grid cell sizes) were done by grouping the LFH data into 10 cluster group (k-mean) classes. One of the cluster group classes was assigned to each block of cells (10 by 10 cells) according to k-means clustering. The number of (10) cluster groups was chosen arbitrarily. The intention for these unsupervised classifications per block were to provide initial segmentations that could be assessed for general agreement with morphological feature regions and patterns identified or manual delineated by investigators. The results of unsupervised classifications per block using arbitrary number of cluster groups for 5 m, 10 m, and 20 m grid cell size DTM's are shown in Figures 9, 10, and 11. These results reveal that the classifications using LFH were generally effective at segmenting primary regions with distinct morphological textures, but also that the analysis is sensitive to the number of classes chosen, the spatial integration scale used, and the resolution of the data. Spatial integration scales for the analysis were a function of the block sizes of ten by ten cells, such that the integration scales for LFH feature vectors from the 5 m, 10 m, and 20 m grids were 50 m, 100 m and 200 m.

5 m grid cell LFH (per block) map

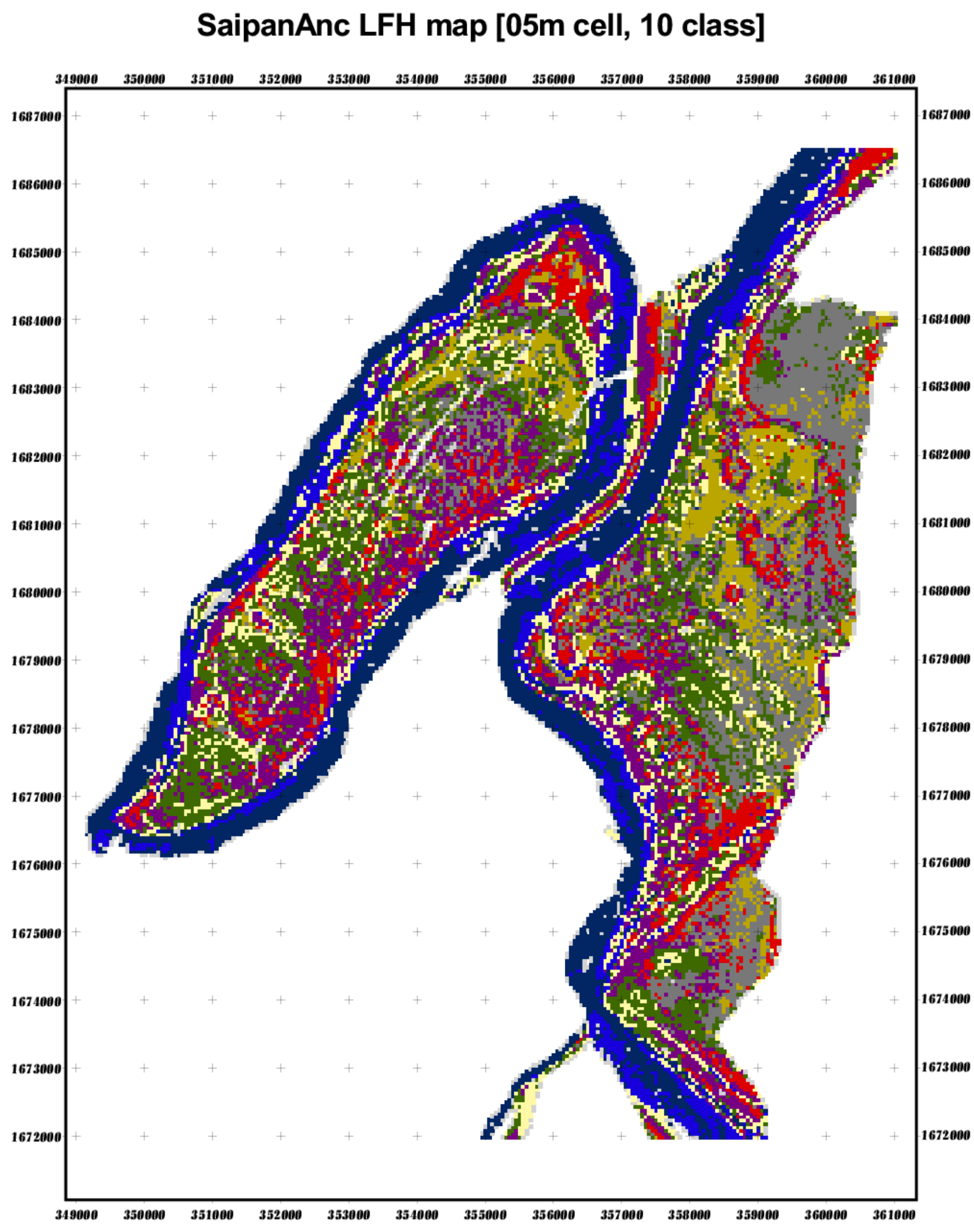

Figure 9. LFH class map for 5 m grid bathymetry data, 10 cluster class groups, and blocksize of 10 by 10 cells. Classes were assigned to each block of cells. Each cell block was assigned one of the classes formed by k-means clustering using 10 groups.

10 m grid cell LFH (per block) map

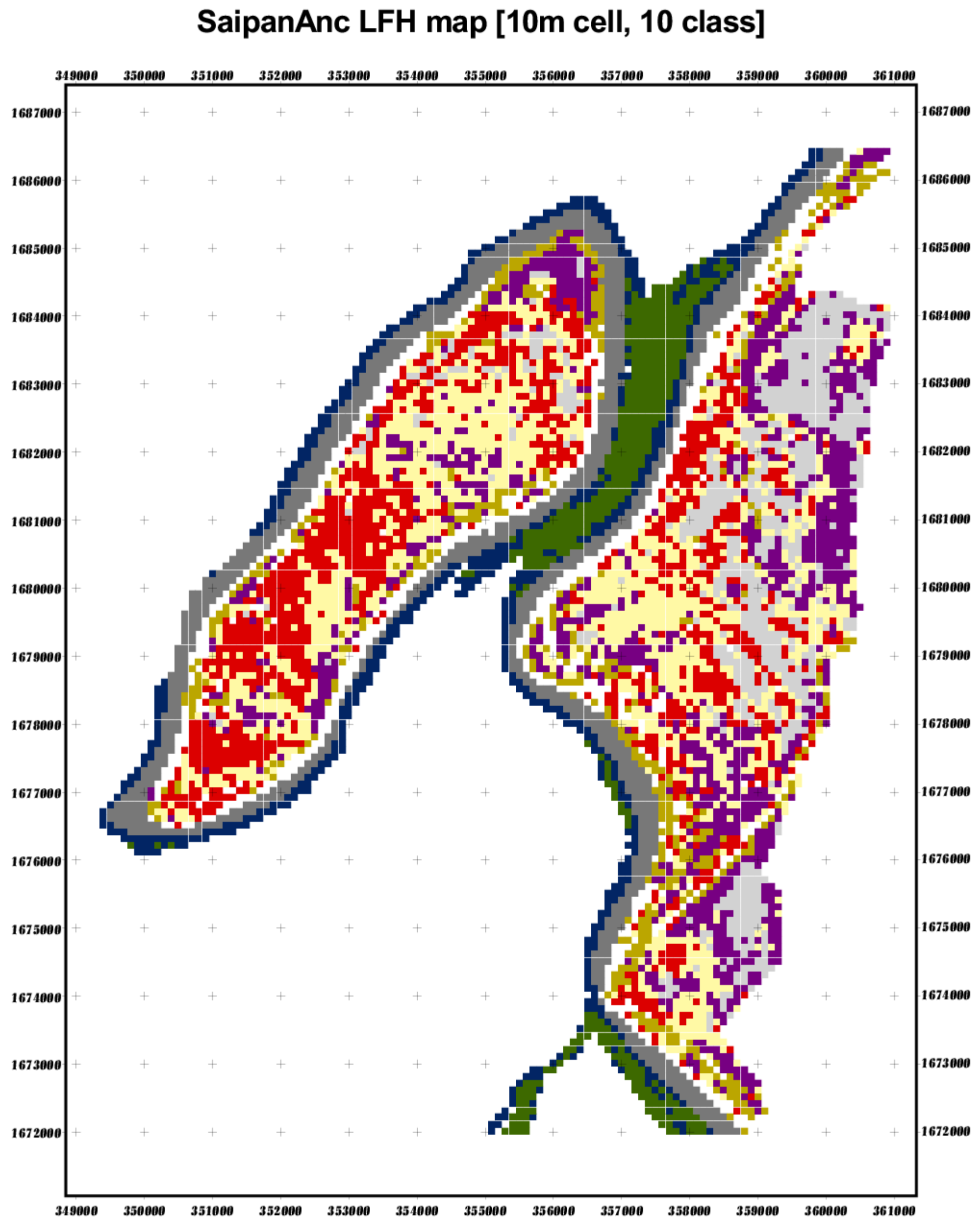

Figure 10. LFH class map for 10 m bathymetric grid from Saipan. Each cell block was assigned one of the classes formed by k-means clustering using 10 groups.

20 m grid cell LFH (per block) map

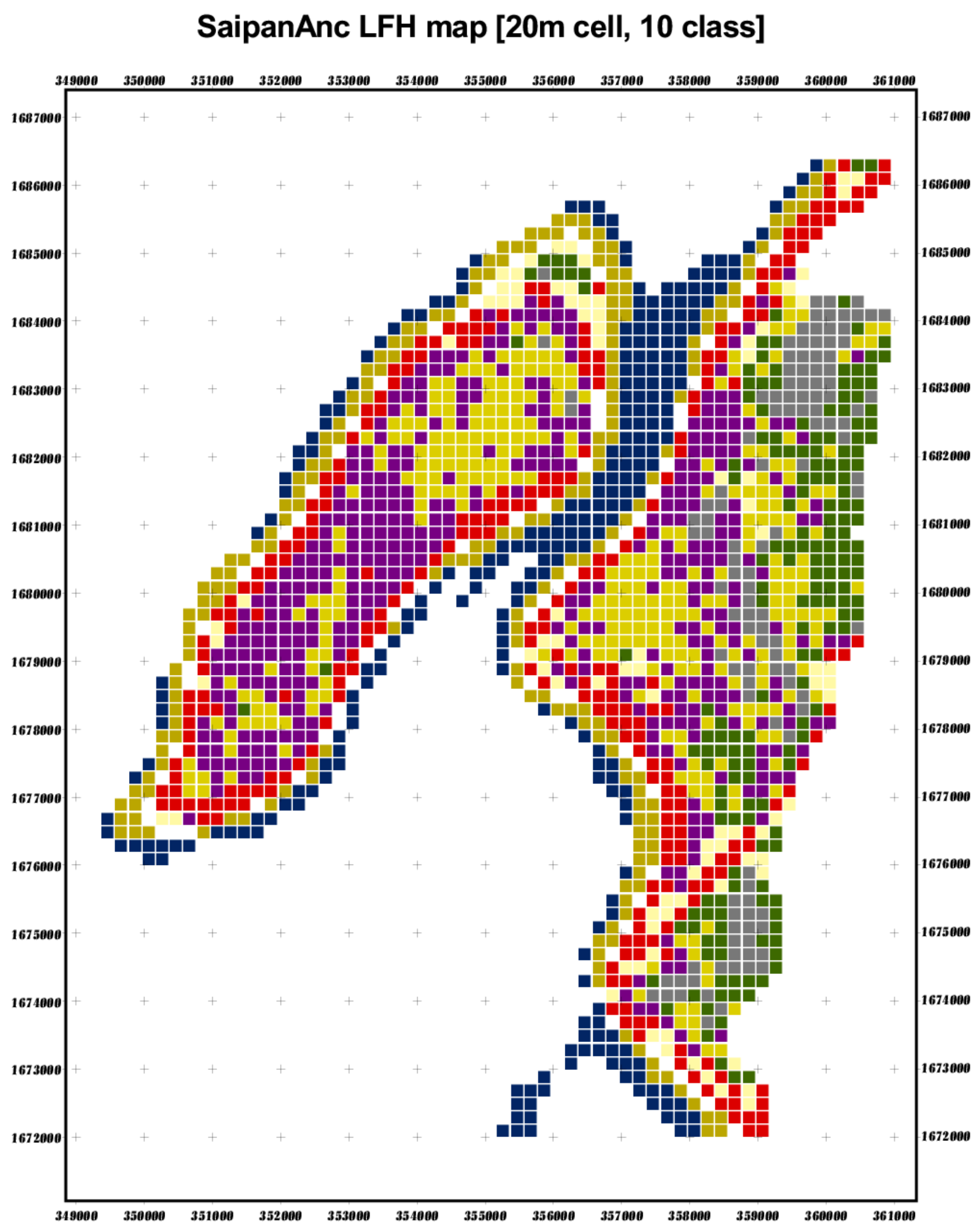

Figure 11. LFH class map for 20 m bathymetric grid from Saipan. Each cell block was assigned one of the classes formed by k-means clustering using 10 groups.

Supervised classification results

Supervised LFH classification from random training samples

The supervised classifications using randomly selected locations to accumulate training sample data used to develop prototype LFH classes. Two sets of random training sample locations were used, one with 10 training samples (Figure 12, Table A-01) and one with 100 training samples (Figure 14, Table A-02). The results of classification by randomly located LFH prototypes from 10 training samples is shown in Figure 13, and the classification by 100 training samples is shown in Figure 15. Classes were sorted according to values of LFH1, LFH2, and LFH3, and a colormap was assigned so going from red to yellow to green to blue corresponded to the representation of relatively higher spatial frequency components of the LFH feature vector. Reds represent classes dominated by lower spatial frequency variation, greens represent moderate spatial frequency variation, and blues represent classes dominated by higher frequency variation.

It could be argued that classification by prototypes generated at randomly located training samples constitutes unsupervised classification. However, the approach is included under the supervised classification section for this study because it requires user intervention for the generation of training sample positions, for determination whether training samples were retained for use, and for the ordering of classes by relative dominance.

Locations of the 10 random samples used to generate prototype LFH classes

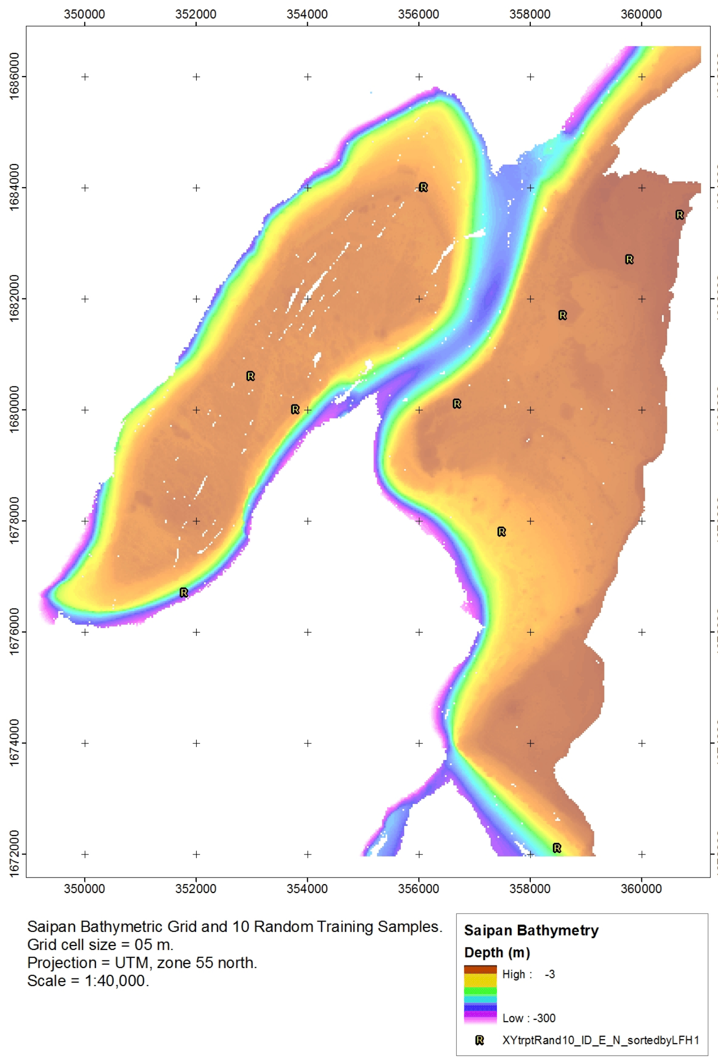

Figure 12. Locations of the 10 random samples used to generate prototype LFH classes (LFHrand10).

Classification by prototype LFH classes from 10 randomly selected samples

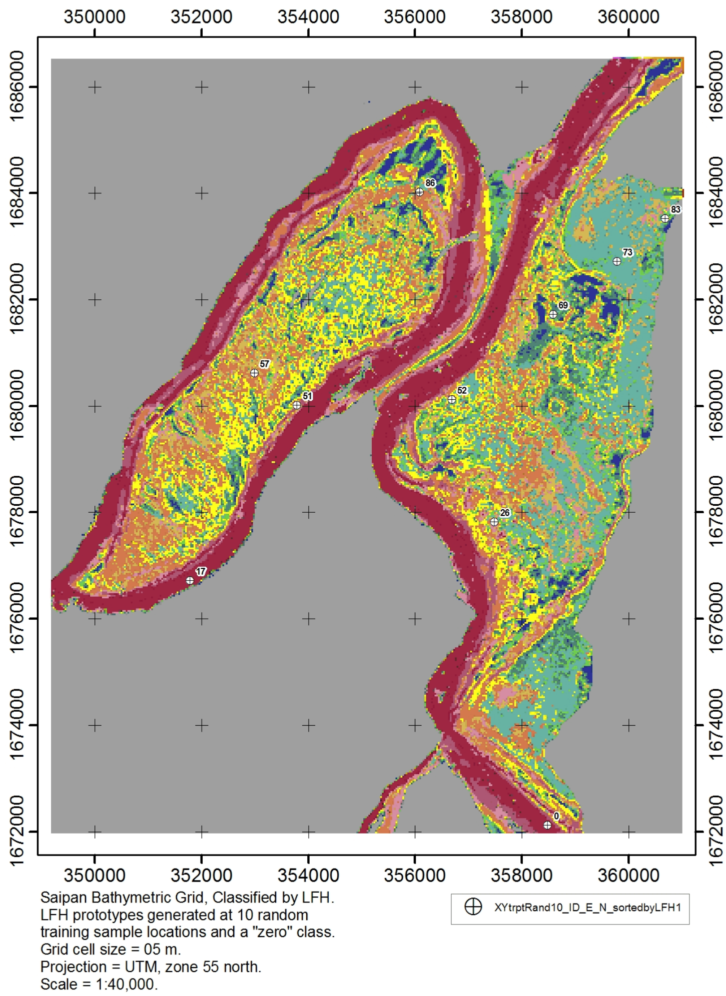

Figure 13. Classification of Saipan 5 m bathymetric grid according to 10 prototype LFH classes generated by 10 randomly selected sample locations. Class assigned to every cell (per cell classification).

Locations of the 100 random samples used to generate prototype LFH classes

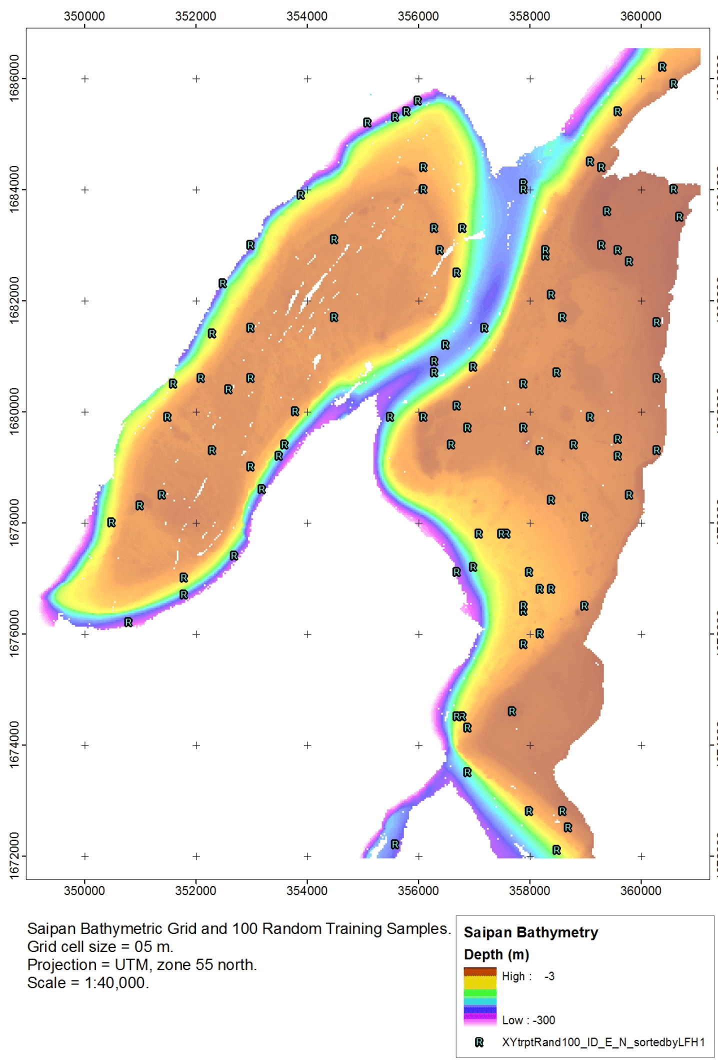

Figure 14. Locations of the 100 random samples used to generate prototype LFH classes (LFHrand100).

Classification by prototype LFH classes from 100 randomly selected points

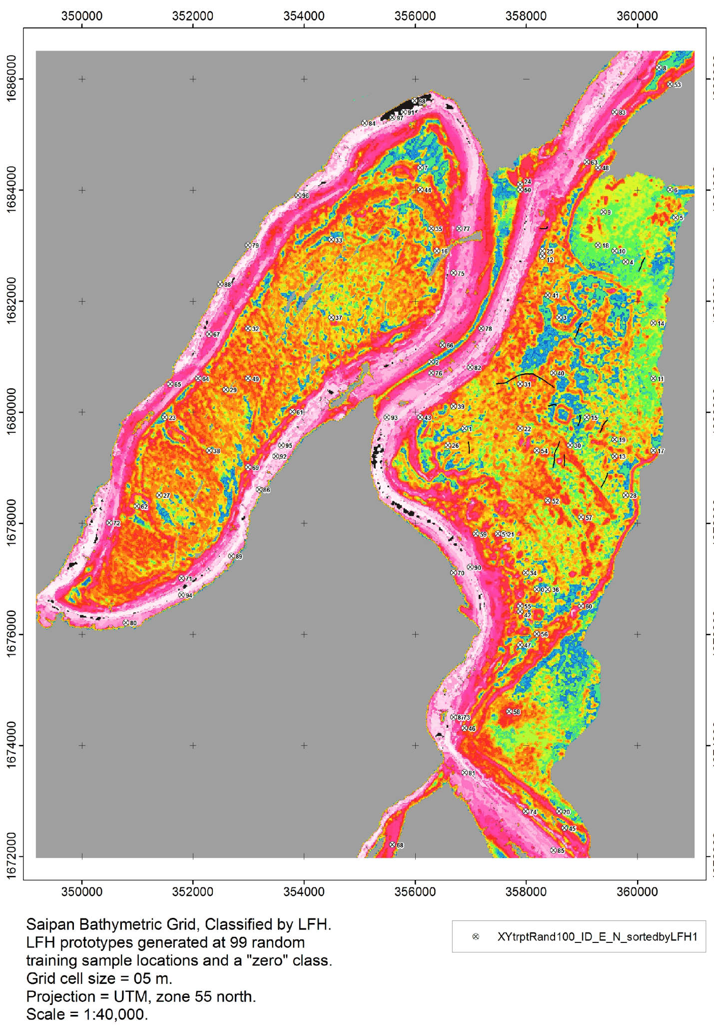

Figure 15. Classification (per cell) of 5 m bathymetric grid from Saipan according to 100 prototype LFH classes generated from data at 100 randomly selected sample locations.

Supervised LFH classification from video data training samples

Supervised classification was implemented using LFH prototypes developed for each of the seven substrate categories described by the video data variable SUBSTR. The video tow transects were all located in the eastern part of the Saipan study area (Figure 16). A close-up view of the video tow transects over the 5 m DTM is shown in Figure 17. The set of 372 video analysis observations for which determinations of substrate were made are shown in Figure 18, and are color-coded by substrate category. The results of LFH classification done according to prototypes developed from locations of the seafloor where the seven substrate categories were identified as well as a "zero" class (Table 3, Table A-07) are shown in Figure 19. This figure depicts the spatial distributions of seafloor LFH texture feature classes assigned values of the most similar substrate class LFH prototype. This "LFHvgt" map predicts substrate type for every DTM grid cell according to texture features developed from the sparse ground-truth data relating substrate type.

Table 3. Names of class prototypes applied for LFH classification by video ground-truth (vgt) training.

ID	Name
0	zero
1	CaCO3 Boulders
2	CaCO3 Rock
3	CaCO3 Rock and Sand
4	CaCO3 Rubble
5	CaCO3 Rubble and Sand
6	Sand
7	Sand and CaCO3 Rock

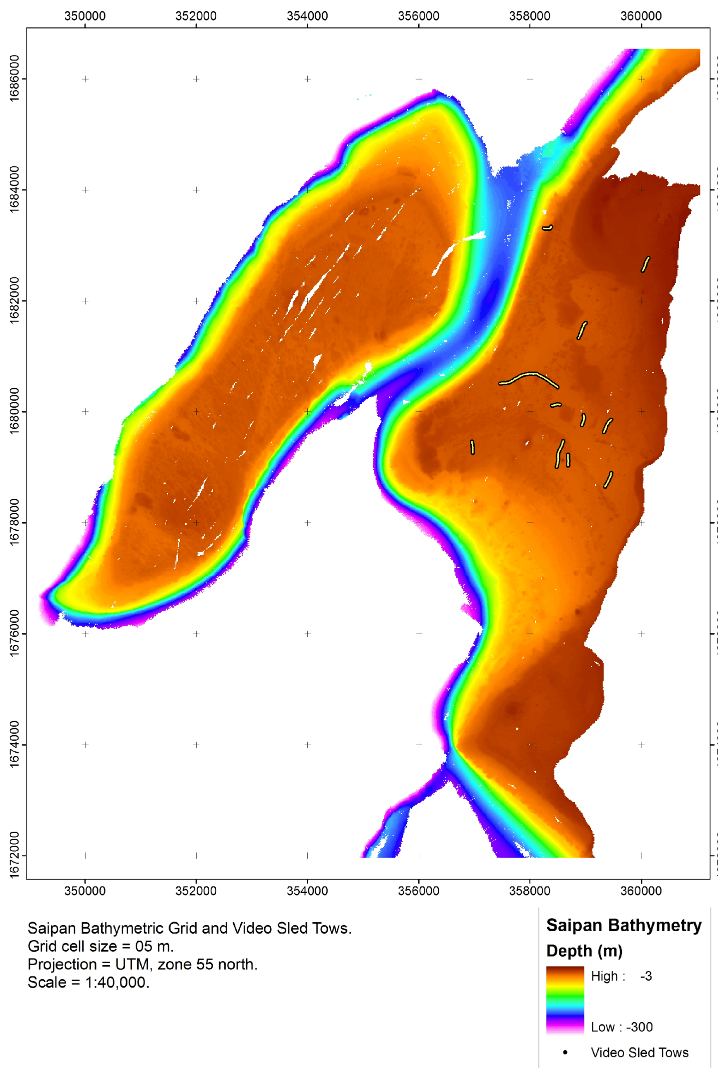

Figure 16. Video tow transects within the Saipan study area, shown over bathymetric data.

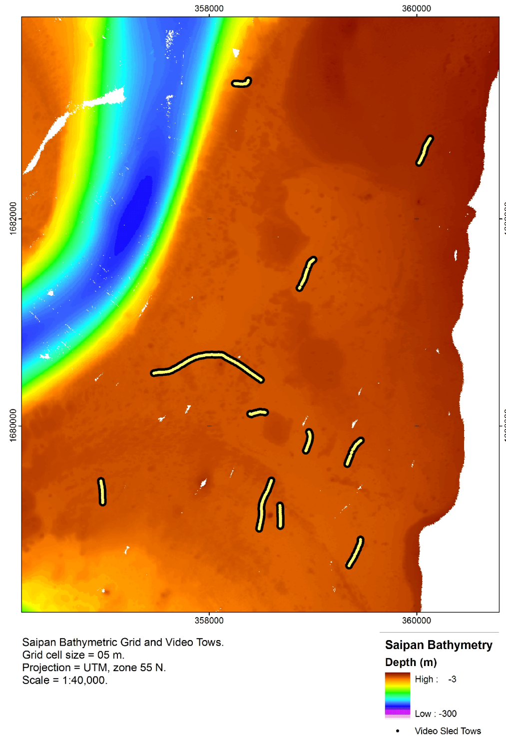

Figure 17. Close-up view of region within Saipan study area containing video tow transects.

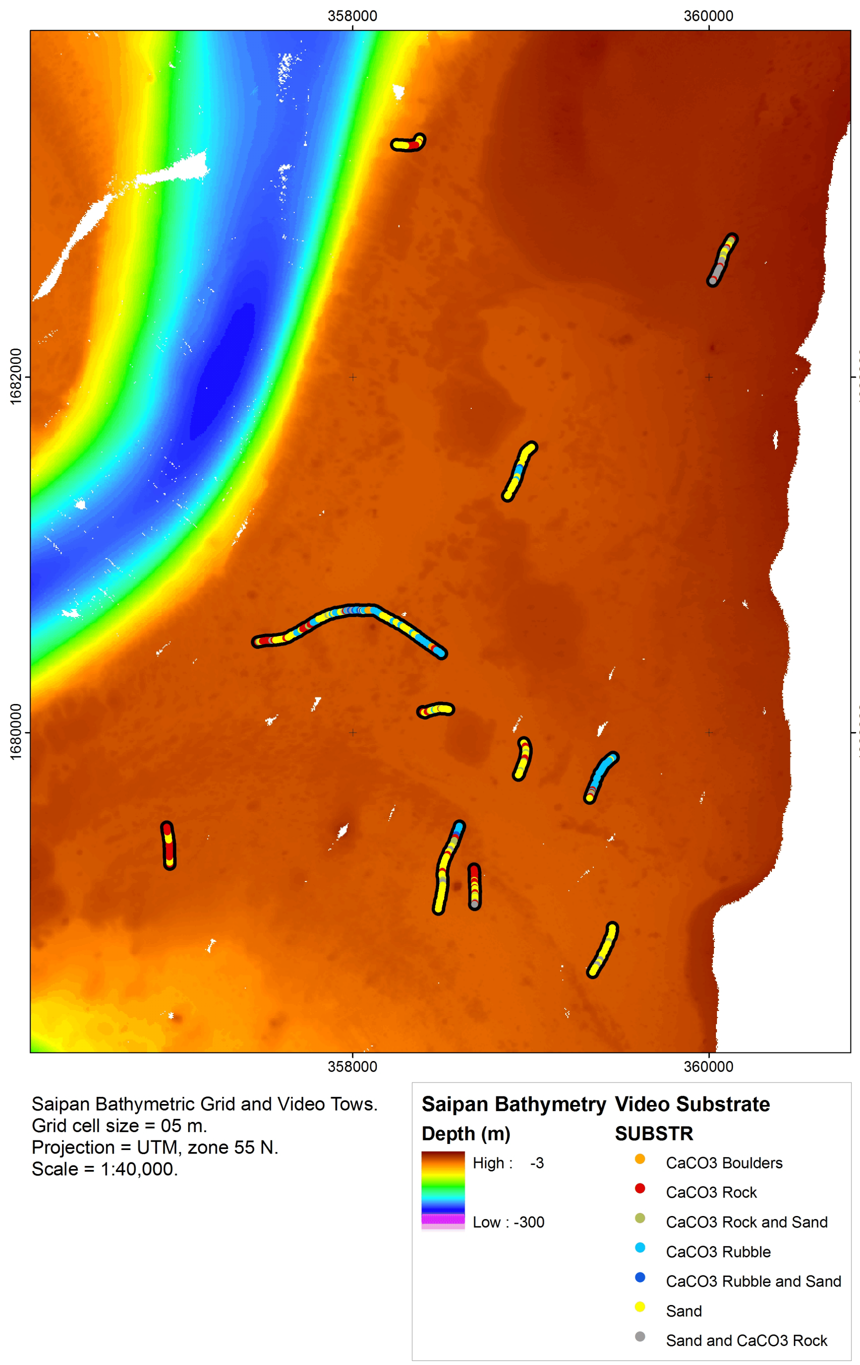

Figure 18. Video transects color coded according to the variable describing substrate (SUBSTR). Seven levels of the substrate variable were identified.

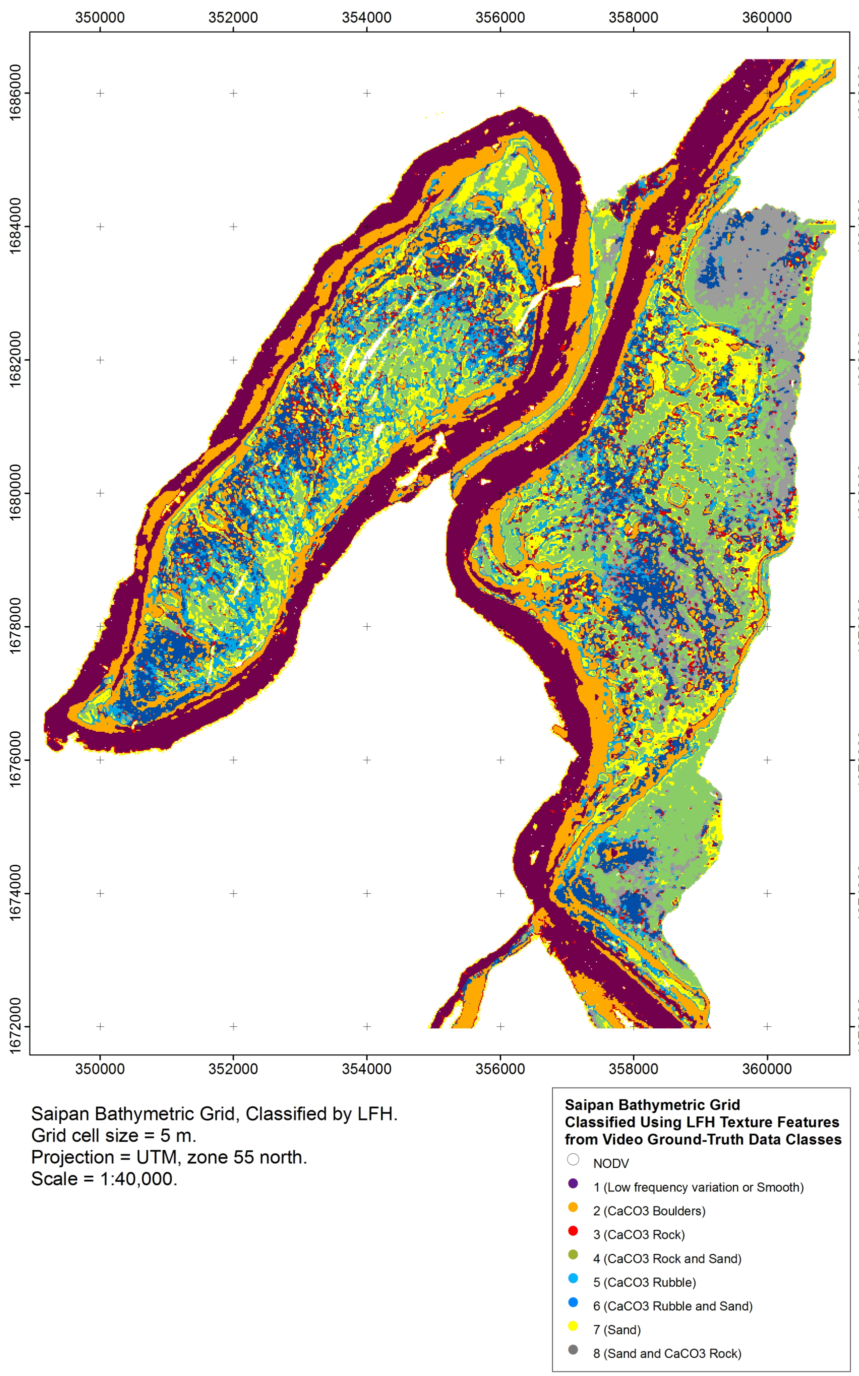

Figure 19. LFHvgt class map (per cell) for the Saipan 5 m bathymetric grid. LFH classes were assigned based upon minimum-distance classification with prototype LFH classes that were generated from video ground-truth (vgt) data. Classes represent identified levels of the video data variable substrate (SUBSTR).

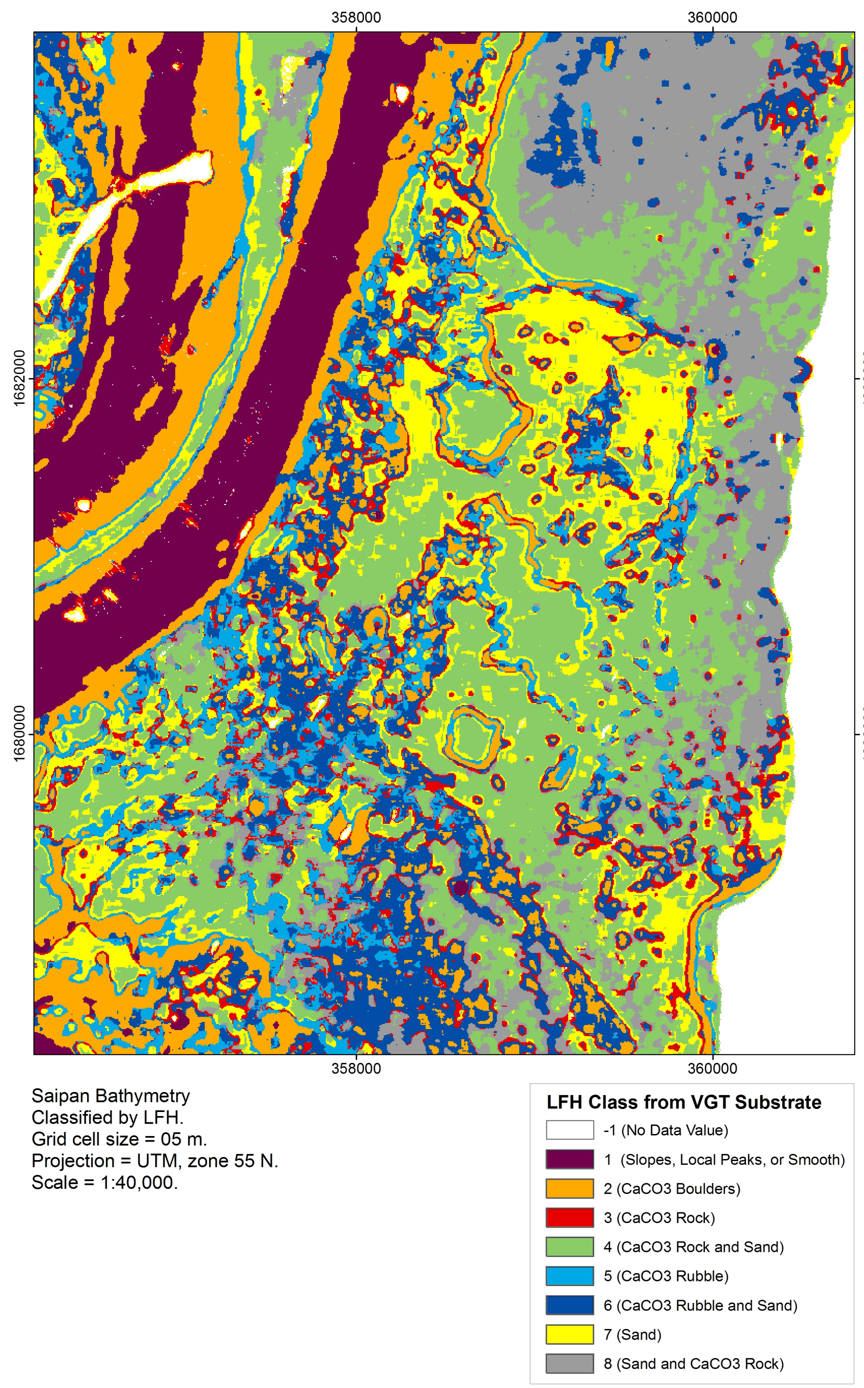

Figure 20. Close-up view of LFHvgt classified (per cell) Saipan 5 m bathymetric grid.

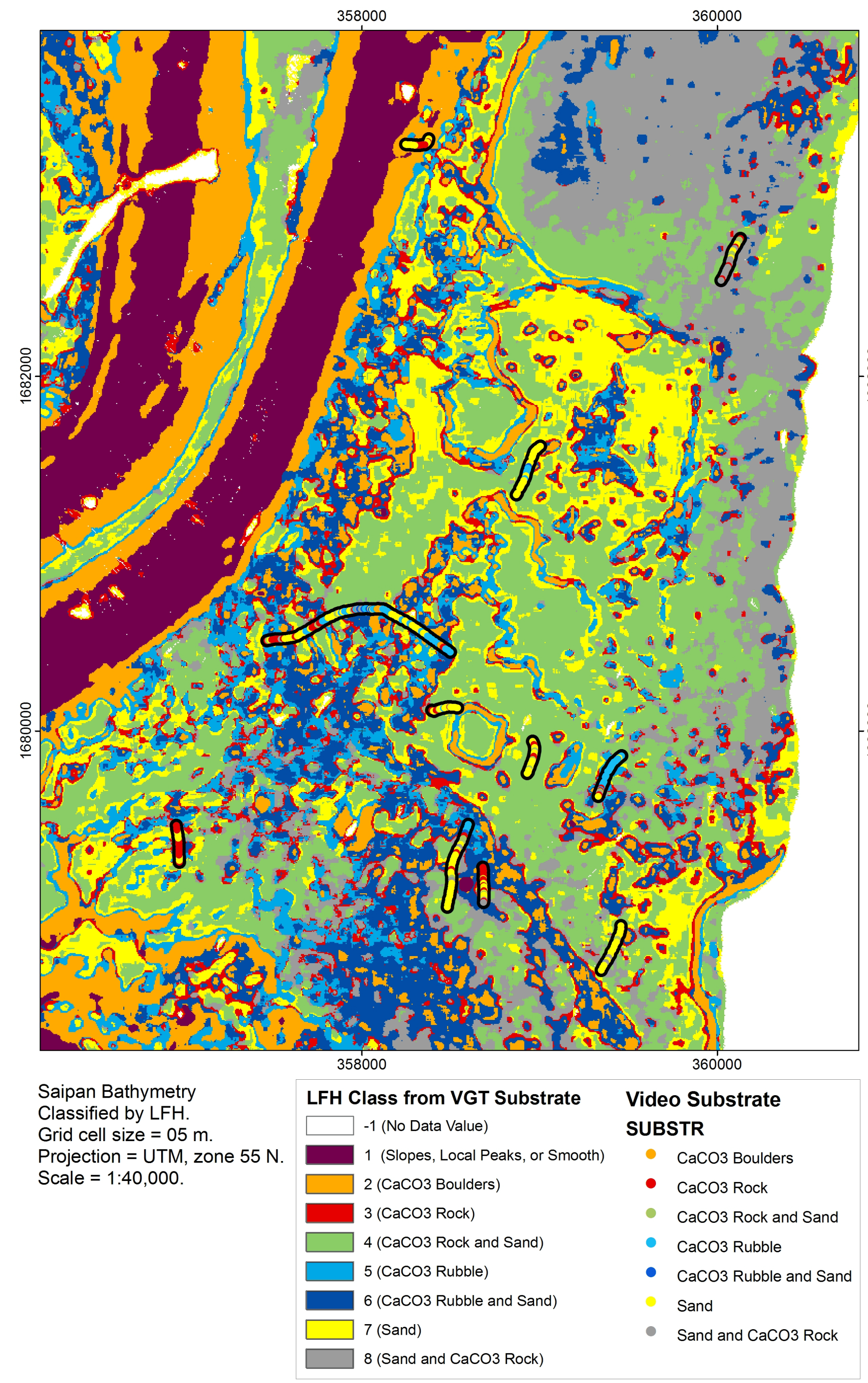

Figure 21. LFHvgt classified (per cell) map close-up view, superimposed by video tow transects color-coded by substrate class.

Supervised LFH classification from video, random, and arbitrary training samples

The primary morphological region spatial distributions are similar to segmentations suggested by previous (random and video ground-truth) classifications. However, the number of named classes is greater since the classes predicted are a combination of the sets of video substrate categories, arbitrary morphologies described from analysis of the DTM, a “zero” class, and a set of classes from the random prototypes that are now considered “background” or “other” classes (Table 4, Table A-08). The “background” or “other” classes are shown colored light gray in Figure 22.

Table 4. Original set membership and names of class prototypes applied for LFH classification by random, arbitrary, and video ground-truth training.

ID	Source	Name
0	General	zero
1	Random	Rand01 (background1)
2	Random	Rand02 (background2)
3	Random	Rand03 (background3)
4	Random	Rand04 (background4)
5	Random	Rand05 (background5)
6	Random	Rand06 (background6)
7	Random	Rand07 (background7)
8	Random	Rand08 (background8)
9	Random	Rand09 (background9)
10	Random	Rand10 (DeepChannelBank)
11	Arbitrary	ChannelBottomNoisy
12	Arbitrary	LargeSlopes
13	Arbitrary	DeepChannelBottom
14	Arbitrary	DredgedChannel
15	Arbitrary	Heterogeneous
16	Arbitrary	MoundsCommon
17	Arbitrary	NEhighfreqrough
18	Arbitrary	ReefBorderedSediment
19	Arbitrary	ReefEdgeW
20	Arbitrary	ReefRidgeSE
21	Arbitrary	SmoothSedimented
22	Arbitrary	SpurGrooveLike
23	VideoGroundTrut	CaCO3 Boulders
24	VideoGroundTrut	CaCO3 Rock
25	VideoGroundTrut	CaCO3 Rock and Sand
26	VideoGroundTrut	CaCO3 Rubble
27	VideoGroundTrut	CaCO3 Rubble and Sand
28	VideoGroundTrut	Sand
29	VideoGroundTrut	Sand and CaCO3 Rock

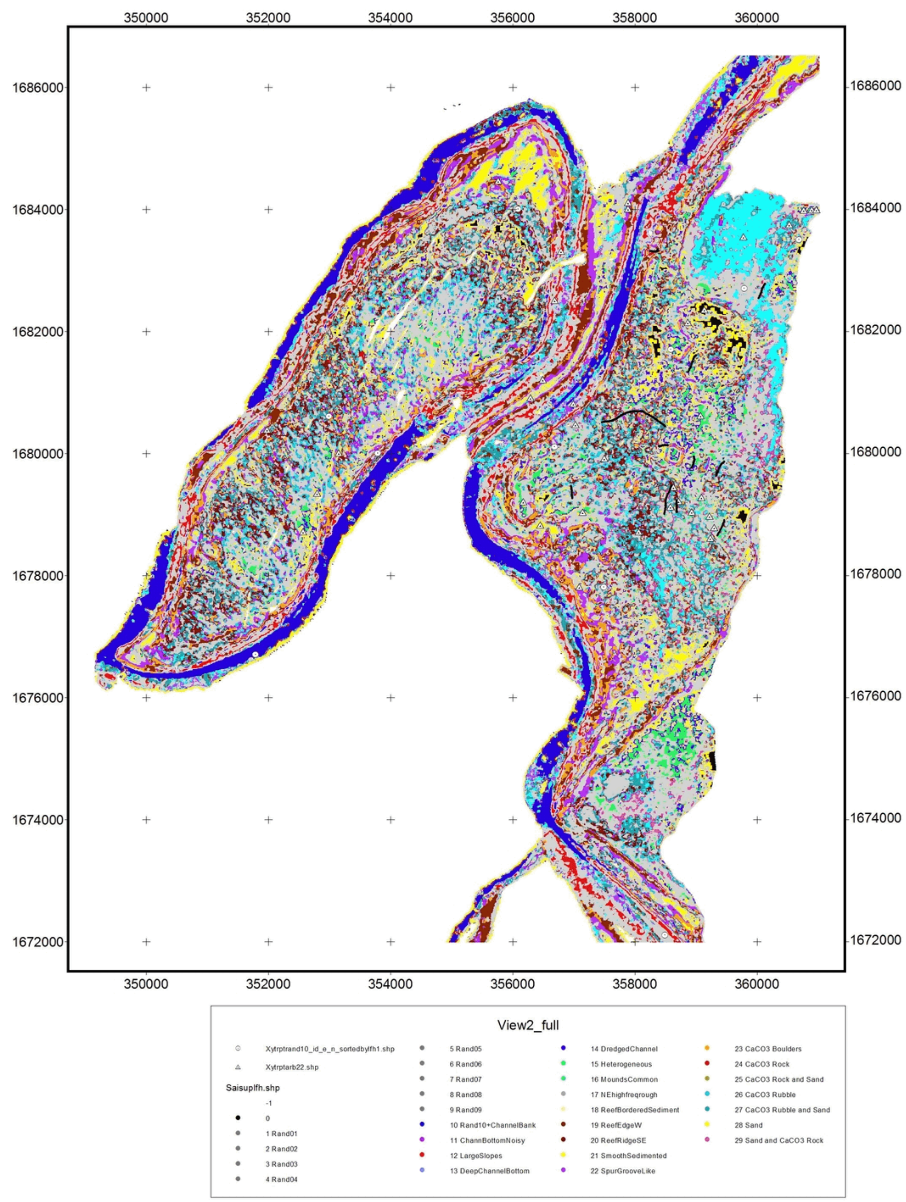

Figure 22. Classification (per cell) of 5 m bathymetric grid from Saipan according to prototype LFH classes generated from data from the combined set of 10 random, 12 arbitrary, and 7 video ground-truth substrate classes, and a “zero” class.

Discussion

LFH and spatial frequencies

The intermediate products of the LFH analysis such as the LFM coefficient maps can be useful for interpretation of seafloor characteristics because they effectively represent the variability of the bathymetry, as the magnitude of waveforms that describe the data series, at multiple spatial frequencies. Effectively, LFH is a multi-scale behaviour of the variation of local bathymetry, and the LFM's represent the magnitude of variability at each spatial scale. Maps of the LFH texture featured classified using cluster analysis are good for segmentation of seafloor into regions of distinctive morphology and data reduction. However, the LFMRGB maps provide an intuitive depiction of seafloor texture distributions because the LFMRGB map weights each color band (red, green, and blue) according to Local Fourier coefficients that effectively describe behavior of seafloor bathymetry at three different spatial scales. Red coloration was assigned to the lowest spatial frequency component, F(1) of the three used for the LFMRGB map; green was applied to F(2), and blue was assigned to F(3). The spatial frequencies represented by F(k) depend upon the resolution of the data and grid cell size, where F(1), F(2), and F(3) represent waveforms with one, two, and three cycles per period, and the period is the length of the data series. For example, the eight local neighbor cell series in a 5 m grid cellsize would have a period of 40 m using the straight line path through cell midpoints. The sets of LFM (Figures 2, 5, 8), LFH, and LFHRGB maps are provided for the three grid resolutions analyzed (5 m, 10 m, and 20 m), and are shown as figures in this document, and the LFH class maps are also included in larger form in separate documents.

Morphologies

The texture feature maps distinguish and segment local morphological textures. There appear to be LFH texture classes (Figure 3) that coincide with regions of different coral reef growth, edges of reefs, deep sloping channels, and relatively flat bottom. Whether the LFH classes actually represent coral species, morphotypes, or sedimentary facies depends upon whether those seafloor attributes have a bathymetric expression at the data resolution. Thus, data resolution and spatial scale of analysis have an important role in interpretation of the texture feature maps. The blocksize (representing a spatial integration scale) and the number of classes used for the unsupervised classification by LFH texture features were arbitrary. Based upon comparison of segmentation results with ground-truth data interpretation, blocksize could be modified and classes could be lumped or split to better fit observations. However, previous efforts have shown that the efforts involved in adjusting class numbers and integration scales were not as effective as using supervised classification approaches, especially when ground-truth data were available.

The intensity and color of the LFMRGB maps (Figures 3, 6, 9) represent the weighted magnitude and relative spatial frequency of local bathymetric variability. The LFMRGB maps from different resolutions suggest similar patterns of relative contributions of the lower, medium, and higher spatial frequency components, as their similar RGB coloration patterns show. The apparent implication of that is that any of the three grid resolutions should produce similar segmentations and seafloor texture classifications for this study area. However, the lower resolution maps (those with larger grid cell sizes) are not expected to relate well to the features of interest and features identifiable in the video image ground-truth data.

The LFH maps from all grid resolutions analyzed show vaguely similar spatial patterns of LFH classes. Note that LFH classes from different resolutions are not color coded the same (Figures 4, 7, 10) since a texture feature from one resolution is not the same as the texture feature from another. The differences in spatial distributions of LFH classes at the different resolutions results primarily from the blocksize extent (integration scale). Ten by ten grid-cell blocksizes were used for each analysis, therefore the length of a side of a block was 50 m, 100 m, and 200 m, from analysis of the 5 m, 10 m, and 20 m grids.   Lower resolution gridding tends to simplify the resultant LFH class segmentation map and obscure some textures with limited spatial coverage.

Unsupervised classification

Unsupervised classifications provided reasonable segmentation and apparently accurate representation of the spatial distributions of different morphological features as shown in Figures. However detailed interpretation of those results were difficult, and apparent misclassifications require arbitrary adjustment of some aspect of the classification procedure, which is an inefficient means of optimization. It was apparent from reviewing the results of unsupervised LFH classification that results from the 5 m grid cell size DTM agreed better with the delineations that would have been produced by investigators. Results from classification of the 10 m grid cell size DTM showed marginally good agreement and would likely be functional. However, results from classification of the 20 m grid cell size DTM per block had limited effectiveness for separating the distinguishable morphological regions. Results from the analysis of the 20 m grid where a class was assigned only for every block reveal that much detail is lost and that classes did not concisely represent the seafloor features of interest. The 10 m grid per block results were slightly better, however it is unclear whether some of the seafloor features of interest had bathymetric expressions that persisted at the 10 m grid resolution. Therefore, the 5 m grid cell size DTM and classification per cell, rather than per block, classifications for additional classification strategies.

The results of unsupervised LFH classification per block revealed that the classifications using LFH were generally effective at segmenting primary regions with distinct morphological textures, but also that the analysis is sensitive to the number of classes chosen, the spatial integration scale used, and especially the resolution of the data. The 5 m grid was determined to be the highest resolution map that could be expected as a standard product. Whether that grid cell size (DTM resolution) is suitable for discrimination and accurate classification of seafloor features according to texture feature analysis depends upon the sizes and bathymetric expression of those particular seafloor feature types.

Supervised classification

Supervised classification according to random training point classes

The class prototypes from the random training samples were sorted according to values of LFH1, LFH2, and LFH3, and a colormap was assigned so going from red to yellow to green to blue corresponded to the representation of relatively higher spatial frequency components of the LFH feature vector. Therefore, the reds represented classes dominated by lower spatial frequency variation, greens represent moderate spatial frequency variation, and blues represent classes dominated by higher frequency variation. Ordering and coloring the classes according to that scheme means that the LFH maps produced from classification according to random training samples (LFHrand) are analogous to discrete representations of the pseudospectral LFMRGB maps. The LFHrand and the LFMRGB maps represent the relative contributions of seafloor roughness occurring at three spatial freqencies. Assignment of long wavelength colors (reds) to low spatial frequency variation components and short wavelength colors (blues) to high spatial frequency components produces maps with intuitive properties. The colors and colorized classes of the LFMRGB and LFHrand maps fit well with the spatial distributions of the major seafloor morphological features identifiable in the DTM.

Supervised classification according to video data classes

This classification was done by assigning to each map grid cell one of the classes represented by the seven LFH prototypes generated from the levels of the video data variable "substrate." Every cell was assigned one of the video substrate classes based upon minimum distance criteria. Alternative classes were not allowed, thus every cell was effectively forced to accept one of the substrate level classes. Many of the apparent misclassifications in the resultant map were caused by classifying only according to the seven video substrate level classes plus a zero class. In other words, all cells were given a class according to minimum distance from a training class. For that to provide an accurate segmentation and classification, it would be necessary that the training sample classes represent all possible classes.

Video position offset and positioning error may have contributed to classification errors. If positioning error or offset existed, then the location identified and used to generate the LFH for the prototype class could include textures from substrates or structures other than those identified by the video analysis. Two approaches to counter that and keep from forcing a potentially erroneous classification involve: 1) setting a threshold distance, beyond which a cell would be classified as "other"; and 2) adding additional training samples from a set of randomly selected or user-specified training positions.

An additional training sample class was added to the set of video ground-truth prototypes in order to accommodate other obvious features in the DTM that were not sampled by the video tows. A “zero” class was added to account for flat, smooth and low frequency variation data. The results from this analysis suggest that the “zero” class represented smooth flat and sloping regions, including the deep channel banks, but also steep peaks within the reef areas.

Considering the results of the supervised classification using video substrate levels and a zero class, it appeared to poorly represent the “sand” class. Initially, it was believed that there were so many "sand" samples, the training sample LFH vector accomodated all of them, thus becoming too broad and incorporating too much variability. It was considered to build a new "sand" LFH class using only some of those, and maybe select them by hand. However, after reviewing these classification results with video tows overlaid, it was apparent that the classification was likely accurate. Viewing the map from what would be considered a large distance, such that only large features and patterns could be seen, there appeared to be several regions that should have been classed “Sand” rather than “Sand and CaCO3 Rock.” Closer inspection revealed that the regions did indeed contain many lumps that were likely CaCO3 rocks or boulders among the otherwise smooth and likely sandy region. Therefore, the classification was retained and the prototype for sand was not altered.

The“LFHvgt” map predicted substrate type for every DTM grid cell according to texture features developed from the sparse ground-truth data relating substrate type. However, the video data did not sample and could not be expected to represent all morphologies, therefore some erroneous predictions, or misclassifications are inevitable.

Supervised classification according to random, arbitrary, and video prototypes

The supervised classification used a set of prototypes derived from random, video data, and inspection of the DTM should provide a more thorough representation of the apparent morphological and substrate classes that existed within the Saipan study area. However, because there are so many classes, the classified map can appear somewhat confusing. It would be best to examine the results of combined set classification using the digital map data interactively such that each class is switched on and off individually while superimposed on the DTM. The spatial distributions and patterns do appear similar to results from classification using random and video ground-truth data LFH prototypes. Some of the predicted classes had prototypes that likely do not specifically represent the morphological class hoped, such as for example reef ridges or reef edges. It is expected that morphologies such as those generally are characterized by feature dimensions not encompassed by the local neighborhood or spatial integration scales incorporated by the LFH. However, many of the other morphological class predictions matched expected spatial distributions and are expected to be accurate predictions of seafloor class when the set of classes used for this analysis is considered.

Classes and interpretations

Some of the classifications resulting from supervised classification using video ground-truth data

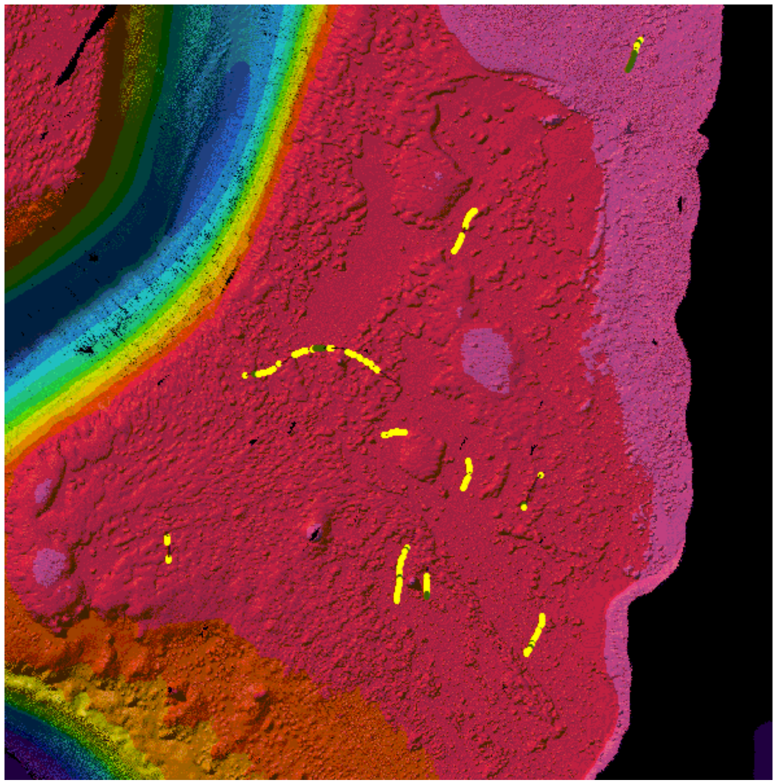

Figure 23. Video tows color coded by "Sand" (yellow) and "Sand and CaCO3" (green) categories of substrate (SUBSTR).

appeared to be misclassifications, or not representative of the video ground-truth designations. Particularly, the sand category from video substrate was observed most frequently in the video data (Figure 22). However, the coverage and distribution of the sand class in the LFHvgt map had a lower proportion coverage of the "Sand" class relative to the "CaCO3 Rock and Sand" class. It should be noted that the video observations where sand was identified were often in close proximity to large features on the seafloor, evident in the DTM (Figure 22). That is important because the texture feature analysis works not only on a local neighborhood of the

DTM depth data, but also involves a spatial integration scale several times larger than the grid cell size. The video images usually represent areas of the seafloor smaller than the area covered by a single 5 m grid cell. Closer examination of the classified map compared to the DTM reveals that the texture feature classification discriminated between homogeneous regions and regions with scattered lumps. Adjacent areas classified as "Sand" and "CaCO3 Rock and Sand" (Figure

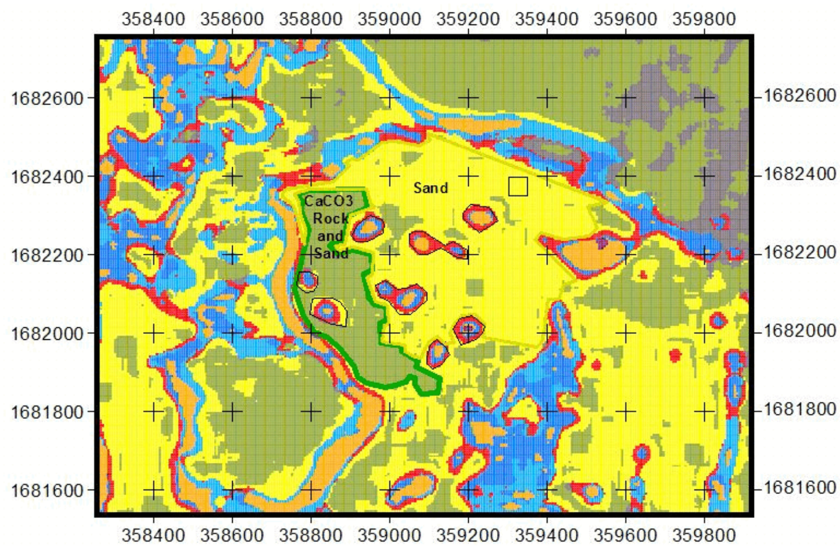

Figure 24. LFH classification by video ground-truth (vgt) prototypes. Close-up view of areas classified as "Sand" and "CaCO3 Rock and Sand". The square near 359400, 1682400 indicates the blocksize or spatial integration scale used for the classification of the 5 m grid cell size bathymetric grid.

23) reveal the seafloor attributes that lead to the unexpected class coverages. The homogeneous, smooth regions were classified as "Sand" and the regions with sparse lumps (perhaps patch reefs) amidst otherwise smooth regions were classified as "CaCO3 Rock and Sand" (Figure 24). In this case, the texture feature classification actually provided what appeared to be a more reliable prediction of the local seafloor properties than the video ground-truth data. Of course, additional ground-truth information is required to determine whether the predictions (that "Sand" exists in

those locations) by classification are accurate. The classification should generally agree with the

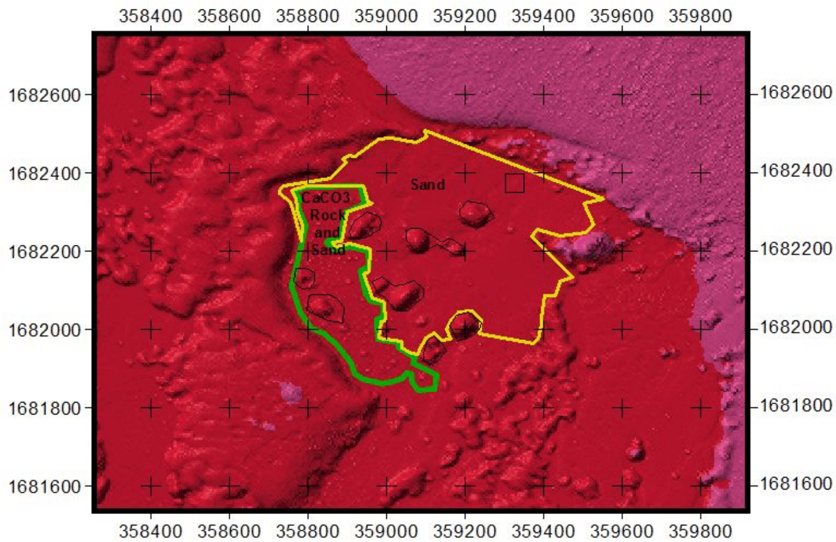

Figure 25. Close-up view of the DTM (5 m grid cell size, shaded bathymetry) showing seafloor features affecting "Sand" and "CaCO3 Rock and Sand" LFH classes.

ground-truth data used to generate training sample derived prototype classes, however this case demonstrates the possibility for disparity. Disparities between what the ground-truth data and classifications relate can be induced by the spatial scales of observation versus spatial integration scale of classification.

Clearly, several of the classifications resulted in similar segmentations, meaning that the map was often divided into the same predominant regions with characteristic and relatively homogeneous textures. These regions were often associated with particular substrates and structures, as identified in the video data, and with morphological characteristics identifiable from the bathymetric map (DTM). Where video data was lacking, and morphological characteristics not clearly identifiable or where seafloor features were not represented by a particular texture, the combined classification allowed for several random prototypes. The set of random classes were considered to be a general background class, or “other” classes that were not previously identified.

References

Canepa, G., Pace, N.G., 2000. Seafloor segmentation from multibeam bathymetric sonar. In: Chevret, P. and Zakharia, M.E., (Eds.) Proceedings of the Fifth European Conference on Underwater Acoustics, ECUA 2000. Lyon, France.

Canepa, G., Pouliquen, E., Pace, N.G., Figoli, A., Franchi, P., 2002. Validation of a seafloor segmentation algorithm for multibeam data. Proceedings of the Sixth European Conference on Underwater Acoustics, ECUA 2002, 24-27 June 2002. Gdansk, Poland, pp. 89-94.

Cutter, G. R., Rzhanov, Y., Mayer, L. A., 2003. Automated segmentation of seafloor bathymetry from multibeam echosounder data using local Fourier histogram texture features. Journal of Experimental Marine Biology and Ecology, 285/286, 355-370.

Huvenne, V. A. I., Blondel, Ph., Henriet, J.-P., 2002. Textural analyses of sidescan sonar imagery from two mound provinces in the Porcupine Seabight. Marine Geology, 189, 323-341.

Minasny, B., McBratney, A.B., 2000. FuzME version 2.1,Australian Centre for Precision Agriculture,The University of Sydney, NSW 2006. (http://www.usyd.edu.au/su/agric/acpa).

Tou, J. T., Gonzalez, R. C., 1974. Pattern recognition principles. Addison-Wesley Publishing Co., Reading, Massachusetts.

Yu, H., Li, M., Zhang, H-J., Feng, J., 2002. Color texture moments for content-based image retrieval. IEEE ICIP 2002, III-929-932.

Zhang, D. S., Lu, G., 2003. Evaluation of similarity measurement for image retrieval. In: Proc. Of IEEE International Conference on Neural Networks and Signal Processing (ICNNSP03), pp. 928-931, Nanjing, China, 14-17 December, 2003.

Zhou, F., Feng, J., Shi, Q., 2001. Texture feature based on local Fourier transform. ICIP 2001 conference proceedings, pp. 610-613.

Appendix

Table A-01. Ten random training sample set positions (UTM Easting, Northing (m), zone 55 north) used for LFHrand10 prototype class vectors.

name	E	N
Rand01	358593.8	1681714.0
Rand02	359793.8	1682714.0
Rand03	360693.8	1683514.0
Rand04	356693.8	1680114.0
Rand05	356093.8	1684014.0
Rand06	352993.8	1680614.0
Rand07	357493.8	1677814.0
Rand08	353793.8	1680014.0
Rand09	358493.8	1672114.0
Rand10	351793.8	1676714.0

Table A-02. One hundred random training sample set positions (UTM Easting, Northing (m), zone 55 north) used for LFHrand100 prototype class vectors.

E	N
358493.8	1672114.0
355593.8	1672214.0
358693.8	1672514.0
357993.8	1672814.0
358593.8	1672814.0
356893.8	1673514.0
358793.8	1674014.0
356893.8	1674314.0
356693.8	1674514.0
356793.8	1674514.0
357693.8	1674614.0
357893.8	1675814.0
358193.8	1676014.0
350793.8	1676214.0
357893.8	1676414.0
357893.8	1676514.0
358993.8	1676514.0
351793.8	1676714.0
358193.8	1676814.0
358393.8	1676814.0
351793.8	1677014.0
356693.8	1677114.0
357993.8	1677114.0
356993.8	1677214.0
352693.8	1677414.0
357093.8	1677814.0
357493.8	1677814.0
357593.8	1677814.0
350493.8	1678014.0
358993.8	1678114.0
350993.8	1678314.0

358393.8	1678414.0
351393.8	1678514.0
359793.8	1678514.0
353193.8	1678614.0
352993.8	1679014.0
353493.8	1679214.0
359593.8	1679214.0
352293.8	1679314.0
358193.8	1679314.0
360293.8	1679314.0
353593.8	1679414.0
356593.8	1679414.0
358793.8	1679414.0
359593.8	1679514.0
356893.8	1679714.0
357893.8	1679714.0
351493.8	1679914.0
355493.8	1679914.0
356093.8	1679914.0
359093.8	1679914.0
353793.8	1680014.0
356693.8	1680114.0
352593.8	1680414.0
351593.8	1680514.0
357893.8	1680514.0
352093.8	1680614.0
352993.8	1680614.0
360293.8	1680614.0
356293.8	1680714.0
358493.8	1680714.0
356993.8	1680814.0
356293.8	1680914.0
356493.8	1681214.0
352293.8	1681414.0
352993.8	1681514.0
357193.8	1681514.0
360293.8	1681614.0
354493.8	1681714.0
358593.8	1681714.0
358393.8	1682114.0
352493.8	1682314.0
356693.8	1682514.0
359793.8	1682714.0
358293.8	1682814.0
356393.8	1682914.0
358293.8	1682914.0
359593.8	1682914.0
352993.8	1683014.0
359293.8	1683014.0
354493.8	1683114.0
356293.8	1683314.0
356793.8	1683314.0
360693.8	1683514.0
359393.8	1683614.0
353893.8	1683914.0
356093.8	1684014.0
357893.8	1684014.0
360593.8	1684014.0
357893.8	1684114.0
356093.8	1684414.0
359293.8	1684414.0
359093.8	1684514.0
355093.8	1685214.0
355593.8	1685314.0
355793.8	1685414.0
359593.8	1685414.0

355993.8	1685614.0
360593.8	1685914.0
360393.8	1686214.0

Table A-03. Video ground-truth sample tow details and positions for analyzed frames.

ID	TO	F	E	N	LATITUDE	LONGITUD	TIME	SYSTE
	W	R				E		M
1	103	1	356972.033	1679260.21	15.1853333	145.66855	09:33:45 AM	SAI
2	103	2	356972.089	1679269.44	15.1854167	145.66855	09:34:15 AM	SAI
3	103	3	356972.157	1679280.5	15.1855167	145.66855	09:34:45 AM	SAI
4	103	4	356972.213	1679289.72	15.1856	145.66855	09:35:15 AM	SAI
5	103	5	356970.442	1679298.95	15.1856833	145.668533	09:35:45 AM	SAI
6	103	6	356970.499	1679308.17	15.1857667	145.668533	09:36:15 AM	SAI
7	103	7	356970.544	1679315.54	15.1858333	145.668533	09:36:45 AM	SAI
8	103	8	356970.6	1679324.77	15.1859167	145.668533	09:37:15 AM	SAI
9	103	9	356970.667	1679335.83	15.1860167	145.668533	09:37:45 AM	SAI
10	103	10	356970.712	1679343.2	15.1860833	145.668533	09:38:15 AM	SAI
11	103	11	356970.779	1679354.26	15.1861833	145.668533	09:38:45 AM	SAI
12	103	12	356968.986	1679359.8	15.1862333	145.668516	09:39:15 AM	SAI
13	103	13	356970.869	1679369.02	15.1863167	145.668533	09:39:45 AM	SAI
14	103	14	356967.38	1679378.26	15.1864	145.6685	09:40:15 AM	SAI
15	103	15	356967.436	1679387.47	15.1864833	145.6685	09:40:45 AM	SAI
16	103	16	356965.654	1679394.86	15.18655	145.668483	09:41:15 AM	SAI
17	103	17	356963.884	1679404.09	15.1866333	145.668466	09:41:45 AM	SAI
18	103	18	356963.94	1679413.32	15.1867167	145.668466	09:42:15 AM	SAI
19	103	19	356962.277	1679422.54	15.1868	145.66845	09:42:45 AM	SAI
20	103	20	356960.507	1679431.77	15.1868833	145.668433	09:43:15 AM	SAI
21	103	21	356958.737	1679441.01	15.1869667	145.668416	09:43:45 AM	SAI
22	103	22	356957.063	1679448.39	15.1870333	145.6684	09:44:15 AM	SAI
23	103	23	356957.119	1679457.61	15.1871167	145.6684	09:44:45 AM	SAI
24	103	24	356955.348	1679466.84	15.1872	145.668383	09:45:15 AM	SAI
25	104	1	358681.925	1679231.43	15.1851667	145.684466	10:14:00 AM	SAI
26	104	2	358683.707	1679224.04	15.1851	145.684483	10:14:30 AM	SAI
27	104	3	358683.651	1679214.83	15.1850167	145.684483	10:15:00 AM	SAI
28	104	4	358685.445	1679209.28	15.1849667	145.6845	10:15:30 AM	SAI
29	104	5	358683.563	1679200.07	15.1848833	145.684483	10:16:00 AM	SAI
30	104	6	358685.334	1679190.84	15.1848	145.6845	10:16:30 AM	SAI
31	104	7	358683.452	1679181.64	15.1847167	145.684483	10:17:00 AM	SAI
32	104	8	358685.234	1679174.25	15.18465	145.6845	10:17:30 AM	SAI
33	104	9	358683.374	1679168.73	15.1846	145.684483	10:18:00 AM	SAI
34	104	10	358683.33	1679161.35	15.1845333	145.684483	10:18:30 AM	SAI
35	104	11	358685.123	1679155.8	15.1844833	145.6845	10:19:00 AM	SAI
36	104	12	358685.09	1679150.27	15.1844333	145.6845	10:19:30 AM	SAI
37	104	13	358685.034	1679141.06	15.18435	145.6845	10:20:00 AM	SAI
38	104	14	358686.709	1679133.67	15.1842833	145.684516	10:20:30 AM	SAI
39	104	15	358684.957	1679128.15	15.1842333	145.6845	10:21:00 AM	SAI
40	104	16	358686.642	1679122.61	15.1841833	145.684516	10:21:30 AM	SAI
41	104	17	358686.598	1679115.24	15.1841167	145.684516	10:22:00 AM	SAI
42	104	18	358686.565	1679109.71	15.1840667	145.684516	10:22:30 AM	SAI
43	104	19	358688.358	1679104.16	15.1840167	145.684533	10:23:00 AM	SAI
44	104	20	358686.498	1679098.64	15.1839667	145.684516	10:23:30 AM	SAI
45	104	21	358686.46	1679092.19	15.1839	145.684516	10:24:00 AM	SAI
46	104	22	358686.421	1679085.73	15.18385	145.684516	10:24:30 AM	SAI
47	104	23	358686.387	1679080.2	15.1838	145.684516	10:25:00 AM	SAI
48	104	24	358686.354	1679074.67	15.18375	145.684516	10:25:30 AM	SAI
49	104	25	358686.321	1679069.14	15.1837	145.684516	10:26:00 AM	SAI
50	104	26	358686.287	1679063.61	15.18365	145.684516	10:26:30 AM	SAI
51	104	27	358686.254	1679058.07	15.1836	145.684516	10:27:00 AM	SAI
52	104	28	358686.21	1679050.7	15.1835333	145.684516	10:27:30 AM	SAI
53	104	29	358688.003	1679045.15	15.1834833	145.684533	10:28:00 AM	SAI
54	104	30	358687.97	1679039.62	15.1834333	145.684533	10:28:30 AM	SAI
55	104	31	358686.099	1679032.26	15.1833667	145.684516	10:29:00 AM	SAI
56	105	1	358961.994	1679941.5	15.1916	145.687033	10:51:30 AM	SAI
57	105	2	358965.495	1679934.1	15.1915333	145.687066	10:52:00 AM	SAI
58	105	3	358969.093	1679924.86	15.19145	145.6871	10:52:30 AM	SAI
59	105	4	358970.756	1679915.64	15.1913667	145.687116	10:53:00 AM	SAI
60	105	5	358972.527	1679906.4	15.1912833	145.687133	10:53:30 AM	SAI

ID	TOW	FR	E	N	LATITUDE	LONGITUDE	TIME	SYSTEM
61	105	6	358972.472	1679897.18	15.1912	145.687133	10:54:00 AM	SAI
62	105	7	358972.417	1679887.97	15.1911167	145.687133	10:54:30 AM	SAI
63	105	8	358970.535	1679878.75	15.1910333	145.687116	10:55:00 AM	SAI
64	105	9	358968.75	1679867.7	15.1909333	145.6871	10:55:30 AM	SAI
65	105	10	358966.868	1679858.5	15.19085	145.687083	10:56:00 AM	SAI
66	105	11	358964.975	1679847.44	15.19075	145.687066	10:56:30 AM	SAI
67	105	12	358961.374	1679838.25	15.1906667	145.687033	10:57:00 AM	SAI
68	105	13	358959.503	1679830.88	15.1906	145.687016	10:57:30 AM	SAI
69	105	14	358955.903	1679821.69	15.1905167	145.686983	10:58:00 AM	SAI
70	105	15	358952.313	1679814.33	15.19045	145.68695	10:58:30 AM	SAI
71	105	16	358948.594	1679803.29	15.19035	145.686916	10:59:00 AM	SAI
72	105	17	358946.819	1679794.08	15.1902667	145.6869	10:59:30 AM	SAI
73	105	18	358943.122	1679786.73	15.1902	145.686866	11:00:00 AM	SAI
74	105	19	358939.521	1679777.53	15.1901167	145.686833	11:00:30 AM	SAI
75	105	20	358935.921	1679768.33	15.1900333	145.6868	11:01:00 AM	SAI
76	105	21	358930.505	1679760.99	15.1899667	145.68675	11:01:30 AM	SAI
77	106	1	358393.619	1680116.41	15.19315	145.681733	11:22:00 AM	SAI
78	106	2	358395.434	1680114.55	15.1931333	145.68175	11:22:30 AM	SAI
79	106	3	358397.153	1680114.54	15.1931333	145.681766	11:23:00 AM	SAI
80	106	4	358398.98	1680114.53	15.1931333	145.681783	11:23:30 AM	SAI
81	106	5	358398.98	1680114.53	15.1931333	145.681783	11:24:00 AM	SAI
83	106	7	358402.514	1680112.67	15.1931167	145.681816	11:25:00 AM	SAI
84	106	8	358404.34	1680112.66	15.1931167	145.681833	11:25:30 AM	SAI
85	106	9	358402.514	1680112.67	15.1931167	145.681816	11:26:00 AM	SAI
86	106	10	358406.156	1680110.8	15.1931	145.68185	11:26:30 AM	SAI
87	106	11	358406.167	1680112.65	15.1931167	145.68185	11:27:00 AM	SAI
88	106	12	358407.886	1680112.64	15.1931167	145.681866	11:27:30 AM	SAI
89	106	13	358413.268	1680114.44	15.1931333	145.681916	11:28:00 AM	SAI
90	106	14	358418.651	1680116.26	15.19315	145.681966	11:28:30 AM	SAI
91	106	15	358425.872	1680119.9	15.1931833	145.682033	11:29:00 AM	SAI
92	106	16	358434.811	1680123.54	15.1932167	145.682116	11:29:30 AM	SAI
93	106	17	358440.194	1680125.34	15.1932333	145.682166	11:30:00 AM	SAI
94	106	18	358447.403	1680127.15	15.19325	145.682233	11:30:30 AM	SAI
95	106	19	358452.786	1680128.96	15.1932667	145.682283	11:31:00 AM	SAI
96	106	20	358458.158	1680128.93	15.1932667	145.682333	11:31:30 AM	SAI
97	106	21	358465.367	1680130.72	15.1932833	145.6824	11:32:00 AM	SAI
98	106	22	358470.75	1680132.54	15.1933	145.68245	11:32:30 AM	SAI
99	106	23	358476.133	1680134.35	15.1933167	145.6825	11:33:00 AM	SAI
100	106	24	358481.505	1680134.32	15.1933167	145.68255	11:33:30 AM	SAI
101	106	25	358486.887	1680136.13	15.1933333	145.6826	11:34:00 AM	SAI
102	106	26	358493.978	1680136.08	15.1933333	145.682666	11:34:30 AM	SAI
103	106	27	358499.35	1680136.05	15.1933333	145.682716	11:35:00 AM	SAI
104	106	28	358502.992	1680134.19	15.1933167	145.68275	11:35:30 AM	SAI
105	106	29	358508.363	1680134.16	15.1933167	145.6828	11:36:00 AM	SAI
106	106	30	358513.735	1680134.13	15.1933167	145.68285	11:36:30 AM	SAI
107	106	31	358517.28	1680134.11	15.1933167	145.682883	11:37:00 AM	SAI
108	106	32	358522.652	1680134.07	15.1933167	145.682933	11:37:30 AM	SAI
109	106	33	358528.013	1680132.19	15.1933	145.682983	11:38:00 AM	SAI
110	106	34	358531.558	1680132.17	15.1933	145.683016	11:38:30 AM	SAI
111	106	35	358535.2	1680130.3	15.1932833	145.68305	11:39:00 AM	SAI
112	106	36	358538.745	1680130.28	15.1932833	145.683083	11:39:30 AM	SAI
114	108	1	359006.054	1681606.3	15.20665	145.68735	08:41:00 AM	Saipan
115	108	2	359002.39	1681604.48	15.2066333	145.687316	08:41:30 AM	Saipan
116	108	3	358998.834	1681602.66	15.2066167	145.687283	08:42:00 AM	Saipan
117	108	4	358995.267	1681598.99	15.2065833	145.68725	08:42:30 AM	Saipan
118	108	5	358991.592	1681595.33	15.20655	145.687216	08:43:00 AM	Saipan
119	108	6	358986.21	1681593.51	15.2065333	145.687166	08:43:30 AM	Saipan
120	108	7	358984.457	1681587.99	15.2064833	145.68715	08:44:00 AM	Saipan
121	108	8	358979.075	1681586.19	15.2064667	145.6871	08:44:30 AM	Saipan
122	108	9	358973.67	1681580.69	15.2064167	145.68705	08:45:00 AM	Saipan
123	108	10	358968.266	1681575.19	15.2063667	145.687	08:45:30 AM	Saipan
124	108	11	358966.395	1681567.82	15.2063	145.686983	08:46:00 AM	Saipan
125	108	12	358962.795	1681558.62	15.2062167	145.68695	08:46:30 AM	Saipan

ID	TOW	FR	E	N	LATITUDE	LONGITUDE	TIME	SYSTEM
126	108	13	358960.913	1681549.41	15.2061333	145.686933	08:47:00 AM	Saipan
127	108	14	358957.323	1681542.06	15.2060667	145.6869	08:47:30 AM	Saipan
130	108	17	358948.144	1681516.29	15.2058333	145.686816	08:49:00 AM	Saipan
131	108	18	358944.555	1681508.95	15.2057667	145.686783	08:49:30 AM	Saipan
132	108	19	358940.954	1681499.74	15.2056833	145.68675	08:50:00 AM	Saipan
133	108	20	358939.083	1681492.39	15.2056167	145.686733	08:50:30 AM	Saipan
134	108	21	358935.483	1681483.18	15.2055333	145.6867	08:51:00 AM	Saipan
135	108	22	358933.601	1681473.98	15.20545	145.686683	08:51:30 AM	Saipan
136	108	23	358930.012	1681466.62	15.2053833	145.68665	08:52:00 AM	Saipan
137	108	24	358928.141	1681459.26	15.2053167	145.686633	08:52:30 AM	Saipan
138	108	25	358924.54	1681450.05	15.2052333	145.6866	08:53:00 AM	Saipan
139	108	26	358922.659	1681440.85	15.20515	145.686583	08:53:30 AM	Saipan
140	108	27	358920.788	1681433.48	15.2050833	145.686566	08:54:00 AM	Saipan
141	108	28	358917.187	1681424.29	15.205	145.686533	08:54:30 AM	Saipan
142	108	29	358911.761	1681415.1	15.2049167	145.686483	08:55:00 AM	Saipan
143	108	30	358909.879	1681405.89	15.2048333	145.686466	08:55:30 AM	Saipan
144	108	31	358904.452	1681396.71	15.20475	145.686416	08:56:00 AM	Saipan
145	108	32	358899.025	1681387.52	15.2046667	145.686366	08:56:30 AM	Saipan
146	108	33	358895.424	1681378.32	15.2045833	145.686333	08:57:00 AM	Saipan
147	108	34	358889.998	1681369.13	15.2045	145.686283	08:57:30 AM	Saipan
150	108	37	358875.543	1681341.56	15.20425	145.68615	08:59:00 AM	Saipan
151	108	38	358870.116	1681332.38	15.2041667	145.6861	08:59:30 AM	Saipan
158	109	2	359462.922	1679859.21	15.1908833	145.6917	09:30:10 AM	SAI
159	109	3	359455.69	1679853.72	15.1908333	145.691633	09:30:40 AM	SAI
160	109	4	359446.74	1679848.24	15.1907833	145.69155	09:31:10 AM	SAI
161	109	5	359441.335	1679842.74	15.1907333	145.6915	09:31:40 AM	SAI
162	109	6	359435.93	1679837.24	15.1906833	145.69145	09:32:10 AM	SAI
163	109	7	359428.688	1679829.92	15.1906167	145.691383	09:32:40 AM	SAI
164	109	8	359421.467	1679826.26	15.1905833	145.691316	09:33:10 AM	SAI
165	109	9	359416.052	1679818.93	15.1905167	145.691266	09:33:40 AM	SAI
166	109	10	359410.636	1679811.58	15.19045	145.691216	09:34:10 AM	SAI
167	109	11	359405.209	1679802.4	15.1903667	145.691166	09:34:40 AM	SAI
168	109	12	359401.619	1679795.04	15.1903	145.691133	09:35:10 AM	SAI
169	109	13	359396.192	1679785.86	15.1902167	145.691083	09:35:40 AM	SAI
170	109	14	359390.765	1679776.66	15.1901333	145.691033	09:36:10 AM	SAI
171	109	15	359385.36	1679771.16	15.1900833	145.690983	09:36:40 AM	SAI
174	109	18	359374.473	1679747.26	15.1898667	145.690883	09:38:10 AM	SAI
175	109	19	359370.883	1679739.91	15.1898	145.69085	09:38:40 AM	SAI
178	109	22	359363.52	1679712.29	15.18955	145.690783	09:40:10 AM	SAI
179	109	23	359359.93	1679704.93	15.1894833	145.69075	09:40:40 AM	SAI
180	109	24	359356.233	1679697.59	15.1894167	145.690716	09:41:10 AM	SAI
181	109	25	359352.621	1679686.54	15.1893167	145.690683	09:41:40 AM	SAI
182	109	26	359349.032	1679679.19	15.18925	145.69065	09:42:10 AM	SAI
183	109	27	359345.324	1679669.99	15.1891667	145.690616	09:42:40 AM	SAI
184	109	28	359341.734	1679662.64	15.1891	145.690583	09:43:10 AM	SAI
185	109	29	359339.875	1679657.12	15.18905	145.690566	09:43:40 AM	SAI
186	109	30	359336.285	1679649.76	15.1889833	145.690533	09:44:10 AM	SAI
187	109	31	359334.403	1679640.55	15.1889	145.690516	09:44:40 AM	SAI
188	109	32	359330.803	1679631.36	15.1888167	145.690483	09:45:10 AM	SAI
189	110	1	357464.829	1680509.25	15.19665	145.673066	10:19:55 AM	SAI
190	110	2	357473.865	1680511.05	15.1966667	145.67315	10:20:25 AM	SAI
191	110	3	357482.793	1680512.83	15.1966833	145.673233	10:20:55 AM	SAI
192	110	4	357491.721	1680514.62	15.1967	145.673316	10:21:25 AM	SAI
193	110	5	357502.475	1680516.41	15.1967167	145.673416	10:21:55 AM	SAI
194	110	6	357513.23	1680518.18	15.1967333	145.673516	10:22:25 AM	SAI
195	110	7	357523.973	1680518.11	15.1967333	145.673616	10:22:55 AM	SAI
196	110	8	357534.728	1680519.89	15.19675	145.673716	10:23:25 AM	SAI
197	110	9	357545.471	1680519.83	15.19675	145.673816	10:23:55 AM	SAI
198	110	10	357556.226	1680521.61	15.1967667	145.673916	10:24:25 AM	SAI
199	110	11	357566.969	1680521.54	15.1967667	145.674016	10:24:55 AM	SAI
200	110	12	357579.55	1680523.3	15.1967833	145.674133	10:25:25 AM	SAI
201	110	13	357590.305	1680525.09	15.1968	145.674233	10:25:55 AM	SAI
202	110	14	357602.885	1680526.86	15.1968167	145.67435	10:26:25 AM	SAI

ID	TOW	FR	E	N	LATITUDE	LONGITUDE	TIME	SYSTEM
203	110	15	357613.64	1680528.63	15.1968333	145.67445	10:26:55 AM	SAI
204	110	16	357624.406	1680532.26	15.1968667	145.67455	10:27:25 AM	SAI
205	110	17	357636.89	1680535.87	15.1969	145.674666	10:27:55 AM	SAI
206	110	18	357645.948	1680541.35	15.19695	145.67475	10:28:25 AM	SAI
207	110	19	357656.736	1680548.66	15.1970167	145.67485	10:28:55 AM	SAI
208	110	20	357671.07	1680555.94	15.1970833	145.674983	10:29:25 AM	SAI
209	110	21	357685.403	1680563.23	15.19715	145.675116	10:29:55 AM	SAI
210	110	22	357698.006	1680568.69	15.1972	145.675233	10:30:25 AM	SAI
211	110	23	357708.805	1680577.84	15.1972833	145.675333	10:30:55 AM	SAI
212	110	24	357719.582	1680583.31	15.1973333	145.675433	10:31:25 AM	SAI
213	110	25	357730.37	1680590.62	15.1974	145.675533	10:31:55 AM	SAI
214	110	26	357741.147	1680596.09	15.19745	145.675633	10:32:25 AM	SAI
215	110	27	357751.924	1680601.55	15.1975	145.675733	10:32:55 AM	SAI
216	110	28	357760.886	1680608.88	15.1975667	145.675816	10:33:25 AM	SAI
217	110	29	357769.944	1680614.36	15.1976167	145.6759	10:33:55 AM	SAI
218	110	30	357778.894	1680619.83	15.1976667	145.675983	10:34:25 AM	SAI
219	110	31	357789.671	1680625.3	15.1977167	145.676083	10:34:55 AM	SAI
220	110	32	357800.448	1680630.77	15.1977667	145.676183	10:35:25 AM	SAI
221	110	33	357809.409	1680638.08	15.1978333	145.676266	10:35:55 AM	SAI
222	110	34	357820.186	1680643.55	15.1978833	145.676366	10:36:25 AM	SAI
223	110	35	357830.952	1680647.18	15.1979167	145.676466	10:36:55 AM	SAI
224	110	36	357840.01	1680652.65	15.1979667	145.67655	10:37:25 AM	SAI
225	110	37	357850.775	1680656.27	15.198	145.67665	10:37:55 AM	SAI
226	110	38	357859.726	1680661.75	15.19805	145.676733	10:38:25 AM	SAI
227	110	39	357872.317	1680665.36	15.1980833	145.67685	10:38:55 AM	SAI
228	110	40	357883.072	1680667.14	15.1981	145.67695	10:39:25 AM	SAI
229	110	41	357892.011	1680670.77	15.1981333	145.677033	10:39:55 AM	SAI
230	110	42	357902.777	1680674.4	15.1981667	145.677133	10:40:25 AM	SAI
231	110	43	357911.694	1680674.35	15.1981667	145.677216	10:40:55 AM	SAI
232	110	44	357920.74	1680677.98	15.1982	145.6773	10:41:25 AM	SAI
233	110	45	357931.495	1680679.76	15.1982167	145.6774	10:41:55 AM	SAI
234	110	46	357942.249	1680681.53	15.1982333	145.6775	10:42:25 AM	SAI
235	110	47	357951.177	1680683.32	15.19825	145.677583	10:42:55 AM	SAI
236	110	48	357960.105	1680685.12	15.1982667	145.677666	10:43:25 AM	SAI
237	110	49	357967.314	1680686.91	15.1982833	145.677733	10:43:55 AM	SAI
238	110	50	357976.243	1680688.7	15.1983	145.677816	10:44:25 AM	SAI
239	110	51	357985.267	1680688.65	15.1983	145.6779	10:44:55 AM	SAI
240	110	52	357997.729	1680688.57	15.1983	145.678016	10:45:25 AM	SAI
241	110	53	358010.299	1680688.5	15.1983	145.678133	10:45:55 AM	SAI
242	110	54	358021.053	1680690.28	15.1983167	145.678233	10:46:25 AM	SAI
243	110	55	358029.97	1680690.23	15.1983167	145.678316	10:46:55 AM	SAI
244	110	56	358038.983	1680688.32	15.1983	145.6784	10:47:25 AM	SAI
245	110	57	358047.9	1680688.27	15.1983	145.678483	10:47:55 AM	SAI
246	110	58	358053.261	1680686.39	15.1982833	145.678533	10:48:25 AM	SAI
247	110	59	358060.459	1680686.35	15.1982833	145.6786	10:48:55 AM	SAI
248	110	60	358064.015	1680688.17	15.1983	145.678633	10:49:25 AM	SAI
249	110	61	358069.387	1680688.14	15.1983	145.678683	10:49:55 AM	SAI
250	110	62	358074.758	1680688.11	15.1983	145.678733	10:50:25 AM	SAI
251	110	63	358080.13	1680688.08	15.1983	145.678783	10:50:55 AM	SAI
252	110	64	358085.501	1680688.04	15.1983	145.678833	10:51:25 AM	SAI
253	110	65	358090.884	1680689.86	15.1983167	145.678883	10:51:55 AM	SAI
254	110	66	358098.071	1680687.97	15.1983	145.67895	10:52:25 AM	SAI
255	110	67	358108.814	1680687.9	15.1983	145.67905	10:52:55 AM	SAI
256	110	68	358117.731	1680687.85	15.1983	145.679133	10:53:25 AM	SAI
257	110	69	358128.452	1680684.1	15.1982667	145.679233	10:53:55 AM	SAI
258	110	70	358142.696	1680676.63	15.1982	145.679366	10:54:25 AM	SAI
259	110	71	358155.21	1680667.34	15.1981167	145.679483	10:54:55 AM	SAI
260	110	72	358167.735	1680659.89	15.19805	145.6796	10:55:25 AM	SAI
261	110	73	358180.164	1680654.28	15.198	145.679716	10:55:55 AM	SAI
262	110	74	358196.223	1680644.97	15.1979167	145.679866	10:56:25 AM	SAI
263	110	75	358212.293	1680637.49	15.19785	145.680016	10:56:55 AM	SAI
264	110	76	358226.634	1680628.19	15.1977667	145.68015	10:57:25 AM	SAI
265	110	77	358242.715	1680622.56	15.1977167	145.6803	10:57:55 AM	SAI

ID	TOW	FR	E	N	LATITUDE	LONGITUDE	TIME	SYSTEM
266	110	78	358255.122	1680613.26	15.1976333	145.680416	10:58:25 AM	SAI
267	110	79	358269.473	1680605.8	15.1975667	145.68055	10:58:55 AM	SAI
268	110	80	358283.706	1680596.49	15.1974833	145.680683	10:59:25 AM	SAI
269	110	81	358296.22	1680587.2	15.1974	145.6808	10:59:55 AM	SAI
270	110	82	358310.464	1680579.73	15.1973333	145.680933	11:00:25 AM	SAI
271	110	83	358322.978	1680570.44	15.19725	145.68105	11:00:55 AM	SAI
272	110	84	358333.677	1680563	15.1971833	145.68115	11:01:25 AM	SAI
273	110	85	358346.084	1680553.71	15.1971	145.681266	11:01:55 AM	SAI
274	110	86	358358.609	1680546.25	15.1970333	145.681383	11:02:25 AM	SAI
275	110	87	358369.296	1680536.97	15.19695	145.681483	11:02:55 AM	SAI
276	110	88	358379.984	1680527.69	15.1968667	145.681583	11:03:25 AM	SAI
277	110	89	358396.032	1680516.53	15.1967667	145.681733	11:03:55 AM	SAI
278	110	90	358412.081	1680505.37	15.1966667	145.681883	11:04:25 AM	SAI
279	110	91	358428.129	1680494.21	15.1965667	145.682033	11:04:55 AM	SAI
280	110	92	358442.362	1680484.9	15.1964833	145.682166	11:05:25 AM	SAI
281	110	93	358458.41	1680473.74	15.1963833	145.682316	11:05:55 AM	SAI
282	110	94	358470.924	1680464.44	15.1963	145.682433	11:06:25 AM	SAI
283	110	95	358485.157	1680455.14	15.1962167	145.682566	11:06:55 AM	SAI
284	110	96	358497.66	1680444	15.1961167	145.682683	11:07:25 AM	SAI
285	111	1	358599.254	1679473.48	15.18735	145.683683	11:24:05 AM	SAI
286	111	2	358595.62	1679458.75	15.1872167	145.68365	11:24:35 AM	SAI
287	111	3	358588.321	1679442.2	15.1870667	145.683583	11:25:05 AM	SAI
288	111	4	358582.85	1679425.64	15.1869167	145.683533	11:25:35 AM	SAI
289	111	5	358577.378	1679409.08	15.1867667	145.683483	11:26:05 AM	SAI
290	111	6	358570.08	1679392.53	15.1866167	145.683416	11:26:35 AM	SAI
291	111	7	358564.608	1679375.97	15.1864667	145.683366	11:27:05 AM	SAI
292	111	8	358555.601	1679361.26	15.1863333	145.683283	11:27:35 AM	SAI
293	111	9	358548.292	1679342.87	15.1861667	145.683216	11:28:05 AM	SAI
294	111	10	358539.297	1679330.02	15.18605	145.683133	11:28:35 AM	SAI
295	111	11	358532.01	1679315.31	15.1859167	145.683066	11:29:05 AM	SAI
296	111	12	358526.549	1679300.59	15.1857833	145.683016	11:29:35 AM	SAI
297	111	13	358521.11	1679289.55	15.1856833	145.682966	11:30:05 AM	SAI
298	111	14	358515.65	1679274.84	15.18555	145.682916	11:30:35 AM	SAI
299	111	15	358512.015	1679260.12	15.1854167	145.682883	11:31:05 AM	SAI
300	111	16	358508.403	1679249.07	15.1853167	145.68285	11:31:35 AM	SAI
301	111	17	358506.488	1679234.33	15.1851833	145.682833	11:32:05 AM	SAI
302	111	18	358504.573	1679219.59	15.18505	145.682816	11:32:35 AM	SAI
303	111	19	358502.765	1679204.85	15.1849167	145.6828	11:33:05 AM	SAI
304	111	20	358502.698	1679193.79	15.1848167	145.6828	11:33:35 AM	SAI
305	111	21	358506.166	1679180.86	15.1847	145.682833	11:34:05 AM	SAI
306	111	22	358506.099	1679169.79	15.1846	145.682833	11:34:35 AM	SAI
307	111	23	358506.021	1679156.88	15.1844833	145.682833	11:35:05 AM	SAI
308	111	24	358505.933	1679142.14	15.18435	145.682833	11:35:35 AM	SAI
309	111	25	358504.017	1679127.4	15.1842167	145.682816	11:36:05 AM	SAI
310	111	26	358502.209	1679112.65	15.1840833	145.6828	11:36:35 AM	SAI
311	111	27	358498.457	1679096.08	15.1839333	145.682766	11:37:05 AM	SAI
312	111	28	358496.649	1679081.34	15.1838	145.68275	11:37:35 AM	SAI
313	111	29	358494.733	1679066.61	15.1836667	145.682733	11:38:05 AM	SAI
314	111	30	358489.273	1679051.88	15.1835333	145.682683	11:38:35 AM	SAI
315	111	31	358487.357	1679037.14	15.1834	145.682666	11:39:05 AM	SAI
316	111	32	358483.712	1679020.57	15.18325	145.682633	11:39:35 AM	SAI
317	111	33	358481.796	1679005.84	15.1831167	145.682616	11:40:05 AM	SAI
318	112	1	359458.904	1678900.4	15.1822167	145.691716	12:03:10 PM	SAI
319	112	2	359458.805	1678883.8	15.1820667	145.691716	12:03:40 PM	SAI
320	112	3	359455.16	1678867.23	15.1819167	145.691683	12:04:10 PM	SAI
321	112	4	359451.526	1678852.49	15.1817833	145.69165	12:04:40 PM	SAI
322	112	5	359444.251	1678839.64	15.1816667	145.691583	12:05:10 PM	SAI
323	112	6	359438.791	1678824.91	15.1815333	145.691533	12:05:40 PM	SAI
324	112	7	359433.33	1678810.2	15.1814	145.691483	12:06:10 PM	SAI
325	112	8	359426.055	1678797.33	15.1812833	145.691416	12:06:40 PM	SAI
326	112	9	359420.594	1678782.61	15.18115	145.691366	12:07:10 PM	SAI
327	112	10	359413.404	1678766.06	15.181	145.6913	12:07:40 PM	SAI
328	112	11	359404.302	1678753.2	15.1808833	145.691216	12:08:10 PM	SAI

ID	TOW	FR	E	N	LATITUDE	LONGITUDE	TIME	SYSTEM
329	112	12	359398.83	1678736.64	15.1807333	145.691166	12:08:40 PM	SAI
330	112	13	359389.824	1678721.95	15.1806	145.691083	12:09:10 PM	SAI
331	112	14	359382.538	1678707.24	15.1804667	145.691016	12:09:40 PM	SAI
332	112	15	359373.532	1678692.54	15.1803333	145.690933	12:10:10 PM	SAI
333	112	16	359364.526	1678677.85	15.1802	145.69085	12:10:40 PM	SAI
334	112	17	359355.424	1678664.99	15.1800833	145.690766	12:11:10 PM	SAI
335	112	18	359348.244	1678650.28	15.17995	145.6907	12:11:40 PM	SAI
336	113	1	360132.061	1682779.67	15.2173167	145.697766	12:53:00 PM	SAI
337	113	2	360126.635	1682770.48	15.2172333	145.697716	12:53:30 PM	SAI
338	113	3	360123.057	1682764.97	15.2171833	145.697683	12:54:00 PM	SAI
339	113	4	360115.804	1682755.8	15.2171	145.697616	12:54:30 PM	SAI
340	113	5	360112.204	1682746.6	15.2170167	145.697583	12:55:00 PM	SAI
341	113	6	360108.615	1682739.24	15.21695	145.69755	12:55:30 PM	SAI
342	113	7	360103.2	1682731.9	15.2168833	145.6975	12:56:00 PM	SAI
343	113	8	360099.504	1682724.55	15.2168167	145.697466	12:56:30 PM	SAI
344	113	9	360094.089	1682717.2	15.21675	145.697416	12:57:00 PM	SAI
345	113	10	360090.5	1682709.85	15.2166833	145.697383	12:57:30 PM	SAI
346	113	11	360085.085	1682702.51	15.2166167	145.697333	12:58:00 PM	SAI
347	113	12	360081.474	1682691.47	15.2165167	145.6973	12:58:30 PM	SAI
348	113	13	360079.582	1682680.42	15.2164167	145.697283	12:59:00 PM	SAI
349	113	14	360077.689	1682669.36	15.2163167	145.697266	12:59:30 PM	SAI
350	113	15	360074.089	1682660.16	15.2162333	145.697233	01:00:00 PM	SAI
351	113	16	360070.478	1682649.12	15.2161333	145.6972	01:00:30 PM	SAI
352	113	17	360070.412	1682638.05	15.2160333	145.6972	01:01:00 PM	SAI
353	113	18	360064.975	1682627.02	15.2159333	145.69715	01:01:30 PM	SAI
354	113	19	360061.268	1682617.83	15.21585	145.697116	01:02:00 PM	SAI
355	113	20	360055.831	1682606.8	15.21575	145.697066	01:02:30 PM	SAI
356	113	21	360050.393	1682595.77	15.21565	145.697016	01:03:00 PM	SAI
357	113	22	360044.956	1682584.74	15.21555	145.696966	01:03:30 PM	SAI
358	113	23	360039.519	1682573.7	15.21545	145.696916	01:04:00 PM	SAI
359	113	24	360035.908	1682562.66	15.21535	145.696883	01:04:30 PM	SAI
360	113	25	360028.645	1682551.64	15.21525	145.696816	01:05:00 PM	SAI
361	113	26	360023.218	1682542.46	15.2151667	145.696766	01:05:30 PM	SAI
362	114	1	358377.315	1683341.54	15.2223	145.6814	01:31:30 PM	SAI
363	114	2	358375.456	1683336.02	15.22225	145.681383	01:32:00 PM	SAI
364	114	3	358373.607	1683332.35	15.2222167	145.681366	01:32:30 PM	SAI
365	114	4	358373.585	1683328.65	15.2221833	145.681366	01:33:00 PM	SAI
366	114	5	358371.844	1683324.98	15.22215	145.68135	01:33:30 PM	SAI
367	114	6	358368.17	1683321.32	15.2221167	145.681316	01:34:00 PM	SAI
368	114	7	358366.429	1683317.63	15.2220833	145.6813	01:34:30 PM	SAI
369	114	8	358362.754	1683313.97	15.22205	145.681266	01:35:00 PM	SAI
370	114	9	358359.198	1683312.15	15.2220333	145.681233	01:35:30 PM	SAI
371	114	10	358355.631	1683308.48	15.222	145.6812	01:36:00 PM	SAI
372	114	11	358351.978	1683308.5	15.222	145.681166	01:36:30 PM	SAI
373	114	12	358346.607	1683308.54	15.222	145.681116	01:37:00 PM	SAI
374	114	13	358343.063	1683308.56	15.222	145.681083	01:37:30 PM	SAI
375	114	14	358335.854	1683306.75	15.2219833	145.681016	01:38:00 PM	SAI
376	114	15	358330.483	1683306.79	15.2219833	145.680966	01:38:30 PM	SAI
377	114	16	358325.101	1683304.98	15.2219667	145.680916	01:39:00 PM	SAI
378	114	17	358319.73	1683305.02	15.2219667	145.680866	01:39:30 PM	SAI
379	114	18	358312.64	1683305.06	15.2219667	145.6808	01:40:00 PM	SAI
380	114	19	358305.454	1683306.94	15.2219833	145.680733	01:40:30 PM	SAI
381	114	20	358298.246	1683305.15	15.2219667	145.680666	01:41:00 PM	SAI
382	114	21	358291.167	1683307.02	15.2219833	145.6806	01:41:30 PM	SAI
383	114	22	358283.97	1683307.07	15.2219833	145.680533	01:42:00 PM	SAI
384	114	23	358276.784	1683308.96	15.222	145.680466	01:42:30 PM	SAI
385	114	24	358267.868	1683309.01	15.222	145.680383	01:43:00 PM	SAI
386	114	25	358260.671	1683309.06	15.222	145.680316	01:43:30 PM	SAI
387	114	26	358253.581	1683309.1	15.222	145.68025	01:44:00 PM	SAI
388	114	27	358246.395	1683310.99	15.2220167	145.680183	01:44:30 PM	SAI

Table A-04. Video ground-truth data for analyzed frames.

TOW	FR	STRUCTURE	SUBSTR	SUBSTMOD	COMPLEX	COVER1	COVER2	COVER3	CORAL PERCE
103	1	Mound	CaCO3 Rock		Med	CCA	Coral	Macroalgae	Sparse
103	2	Mound; Plain	Sand	Scattered boulders	Low	Sand	CaCO3 Rock		Sparse
103	3	Plain	Sand	Scattered boulders	Low	Sand	CaCO3 Rock		None
103	4	Plain; Mound	Sand	Ripples	Low	Sand	CaCO3 Rock		Sparse
103	5	Mound	CaCO3 Rock	Overhangs	Med	CCA	Coral	Macroalgae	Moderate
103	6	Mound	CaCO3 Rock	Overhangs	Med	CCA	Coral	Macroalgae	Moderate
103	7	Mound	CaCO3 Rock	Overhangs	Med	CCA	Coral	Macroalgae	Moderate
103	8	Mound; Plain	CaCO3 Rock	Overhangs	Med	CCA	Sand	Coral	Sparse
103	9	Mound	CaCO3 Rock		Med	CCA	Coral	Macroalgae	Moderate
103	10	Mound	CaCO3 Rock			CCA	Coral	Macroalgae	Sparse
103	11	Mound	CaCO3 Rock			CCA	Coral	Macroalgae	Moderate
103	12	Mound	CaCO3 Rock			CCA	Coral	Macroalgae	Moderate
103	13	Mound	CaCO3 Rock		Med	CCA	Coral	Macroalgae	Sparse
103	14	Mound-Channel	CaCO3 Rock		Med	CCA	Coral	Macroalgae	Sparse
103	15	Mound	CaCO3 Rock		Med	CCA	Coral	Macroalgae	Sparse
103	16	Plain	Sand		Low	Sand			None
103	17	Plain	Sand	Ripples	Low	Sand			None
103	18	Plain	Sand	Ripples; Scattered boulders	Low	Sand	CaCO3 Rock		None
103	19	Plain	Sand	Ripples	Low	Sand			None
103	20	Plain; Mound	Sand	Ripples; Scattered boulders	Low	Sand	CaCO3 Rock		None
103	21	Mound	CaCO3 Rock		Med	CCA	Coral	Macroalgae	Sparse
103	22	Mound	CaCO3 Rock		Med	CCA	Soft Coral	Coral	Sparse
103	23	Mound	CaCO3 Rock	Overhangs	High	CCA	Coral	Macroalgae	Moderate
103	24	Mound	CaCO3 Rock		High	CCA	Coral	Macroalgae	Sparse
104	1	Mound	CaCO3 Rock		Low	CaCO3 Rock			Unknown
104	2	Mound	CaCO3 Rock	Sand depression	Low	CaCO3 Rock	Sand		Unknown
104	3	Mound	CaCO3 Rock		Low	CCA	Coral		Sparse
104	4	Mound	CaCO3 Rock		Med	CCA	Coral		Sparse
104	5	Mound	CaCO3 Rock		Med	CCA	Coral		Sparse
104	6	Mound	CaCO3 Rock		Low	CCA	Coral		Unknow

TOW	FR	STRUCTURE	SUBSTR	SUBSTMOD	COMPLEX	COVER1	COVER2	COVER3	CORAL PERCEn
104	7	Mound	CaCO3 Rock		Low	CCA	Coral		Sparse
104	8	Mound	CaCO3 Rock		Low	CCA	Coral		Unknown
104	9	Channel	Sand		Low	Sand	CaCO3 Rock		Unknown
104	10	Mound	CaCO3 Rock		Low	CaCO3 Rock			Unknown
104	11	Mound	CaCO3 Rock		Low	CaCO3 Rock			Unknown
104	12	Mound	CaCO3 Rock		Low	CaCO3 Rock			Unknown
104	13	Plain	Sand	Ripples	Low	Sand			Unknown
104	14	Plain	Sand	Ripples	Low	Sand	CaCO3 Rock		Unknown
104	15	Mound	CaCO3 Rock		Med	CCA	Sand		Sparse
104	16	Plain	Sand	Ripples	Low	Sand			None
104	17	Plain	Sand	Ripples; Scattered boulders	Low	Sand	CCA		None
104	18	Plain	Sand	Patch Reef; Ripples	Med	Sand	CCA	Macroalgae	None
104	19	Plain; Mound	Sand	Ripples	Low	Sand	CaCO3 Rock		Unknown
104	20	Mound	CaCO3 Rock		Med	CCA	Macroalgae	Coral	Sparse
104	21	Mound	CaCO3 Rock	Sand	Med	CCA	Sand	Macroalgae	Sparse
104	22	Plain	Sand	Ripples	Low	Sand	CaCO3 Rock		None
104	23	Mound; Plain	CaCO3 Rock; Sand	Ripples	Med	Sand	CCA	Coral	Sparse
104	24	Plain	Sand	Ripples	Low	Sand			None
104	25	Plain	Sand	Infauna	Low	Sand			None
104	26	Plain	Sand	Infauna	Low	Sand			None
104	27	Plain	Sand	Infauna	Low	Sand			None
104	28	Plain	Sand	Infauna	Low	Sand			None
104	29	Plain; Mound	Sand; CaCO3 Rock		Low	Sand	CaCO3 Rock		Unknown
104	30	Mound; Plain	CaCO3 Rock		Low	Sand	CaCO3 Rock	Macroalgae	Sparse
104	31	Plain; Mound	Sand; CaCO3 Rock		Low	Sand	CaCO3 Rock		None
105	1	Plain	Sand	Ripples	Low	Sand			None
105	2	Plain	Sand	Ripples	Low	Sand			None
105	3	Mound	CaCO3 Rock	Overhangs	Med	CCA	Macroalgae	Coral	Sparse
105	4	Mound	CaCO3 Rock		Med	CCA	Macroalgae	Coral	Sparse
105	5	Plain	Sand	Ripples	Low	Sand			None
105	6	Plain	Sand	Ripples; Scattered boulders	Low	Sand	CCA	Coral	Sparse

TOW	FR	STRUCTURE	SUBSTR	SUBSTMOD	COMPLEX	COVER1	COVER2	COVER3	CORAL PERCE
105	7	Plain	CaCO3 Rock; Sand	Patch Reef; Ripples	Med	CCA	Sand	Macroalgae	Sparse
105	8	Plain	Sand	Ripples; Scattered boulders	Low	Sand	CaCO3 Rock		None
105	9	Plain	Sand	Ripples; Scattered boulders	Low	Sand	CaCO3 Rock		None
105	10	Mound	CaCO3 Rock		Med	CCA	Macroalgae	Sand	Unknown
105	11	Mound	CaCO3 Rock		Med	CCA	Macroalgae	Coral	Sparse
105	12	Mound; Plain	CaCO3 Rock; Sand		Med	CaCO3 Rock	Sand		Unknown
105	13	Plain	Sand	Scattered boulders; Ripples	Low	Sand	CaCO3 Rock		None
105	14	Plain	Sand	Ripples	Low	Sand			None
105	15	Plain	Sand	Ripples	Low	Sand			None
105	16	Plain	Sand	Ripples; Scattered boulders	Low	Sand	CaCO3 Rock		None
105	17	Plain	Sand	Ripples	Low	Sand			None
105	18	Plain; Mound	CaCO3 Rock; Sand		Low	Sand	CaCO3 Rock		None
105	19	Plain	Sand	Scattered boulders; Ripples	Low	Sand	CaCO3 Rock		None
105	20	Plain	Sand	Scattered boulders; Ripples	Low	Sand	CaCO3 Rock		None
105	21	Plain	Sand	Scattered boulders; Ripples	Low	Sand	CaCO3 Rock		None
106	1	Mound	CaCO3 Rock		Med	CCA	Macroalgae		Unknown
106	2	Mound	CaCO3 Rock		Med	CCA	Macroalgae		None
106	3	Mound	CaCO3 Rock		Med	CCA	Macroalgae	Coral	Sparse
106	4	Mound	CaCO3 Rock		Med	CCA	Macroalgae		None
106	5	Mound	CaCO3 Rock		Med	CCA	Macroalgae		None
106	7	Mound; Plain	CaCO3 Rock; Sand	Ripples	Low	Sand	CCA	Macroalgae	None
106	8	Plain	Sand	Scattered boulders;	Low	Sand	CaCO3 Rock		Unknown

TO W	F R	STRUCTURE	SUBSTR	SUBSTMOD	COMPLEX	COVER1	COVER2	COVER3	CORAL PERCE
				Ripples					
106	9	Plain	Sand	Scattered	Low	Sand	CaCO3 Rock		None
				boulders;					
				Ripples					
106	10	Plain	Sand	Ripples	Low	Sand			None
106	11	Plain	Sand	Scattered	Low	Sand	CaCO3 Rock		None
				boulders;					
				Ripples					
106	12	Plain	Sand	Patch Reef;	Med	Sand	CCA	Macroalgae	None
				Ripples					
106	13	Plain	Sand	Scattered	Low	Sand	CaCO3 Rock		Unknow
				boulders;					n
				Ripples					
106	14	Mound	CaCO3 Rock		Low	CCA	Macroalgae	Coral	Sparse
106	15	Mound	CaCO3 Rock		Med	CCA	Macroalgae	Coral	Sparse
106	16	Mound; Plain	CaCO3 Rock;	Ripples	Low	Sand	CCA	Macroalgae	Sparse
			Sand						
106	17	Plain	Sand	Scattered	Low	Sand	CaCO3 Rock		None
				boulders;					
				Ripples					
106	18	Plain	Sand	Ripples	Low	Sand			None
106	19	Plain	Sand	Scattered	Low	Sand			None
				boulders;					
				Ripples					
106	20	Mound	CaCO3 Rubble		Med	CCA	Macroalgae	Sand	None
106	21	Plain	Sand	Scattered	Low	Sand	CCA	Macroalgae	None
				rubble; Ripples					
106	22	Plain	Sand	Ripples	Low	Sand			None
106	23	Plain	Sand	Ripples	Low	Sand			None
106	24	Plain	Sand	Ripples	Low	Sand			None
106	25	Plain	Sand	Scattered	Low	Sand			None
				boulders;					
				Ripples					
106	26	Mound	CaCO3 Rock	Overhangs	Med	CCA	Macroalgae		None
106	27	Mound; Plain	CaCO3 Rock;	Ripples	Low	Sand	CCA	Macroalgae	None
			Sand						
106	28	Plain	Sand	Scattered	Low	Sand	CCA	Macroalgae	None
				boulders;					
				Ripples					
106	29	Plain	Sand	Ripples	Low	Sand			None
106	30	Plain	Sand	Scattered	Low	Sand	CCA	Macroalgae	None
				boulders;					
				Ripples					
106	31	Plain	Sand	Scattered	Low	Sand	CCA	Macroalgae	None

TOW	FR	STRUCTURE	SUBSTR	SUBSTMOD	COMPLEX	COVER1	COVER2	COVER3	CORAL PERCE
				boulders; Ripples					
106	32	Plain	Sand	Scattered boulders; Ripples	Low	Sand	CCA	Macroalgae	None
106	33	Plain	Sand	Scattered boulders; Ripples	Low	Sand	CaCO3 Rock		None
106	34	Plain	Sand	Scattered boulders; Ripples	Low	Sand	CaCO3 Rock		Unknown
106	35	Plain	Sand	Scattered boulders; Ripples	Low	Sand	CCA	Macroalgae	None
106	36	Plain	Sand	Scattered boulders; Ripples	Low	Sand	CCA	Macroalgae	None
108	1	Plain	Sand	Ripples	Low	Sand			None
108	2	Plain	Sand	Ripples	Low	Sand			None
108	3	Plain	Sand	Ripples	Low	Sand			None
108	4	Plain	Sand	Ripples	Low	Sand			None
108	5	Plain	Sand	Ripples	Low	Sand			None
108	6	Plain	Sand	Ripples	Low	Sand			None
108	7	Plain	Sand	Ripples	Low	Sand			None
108	8	Plain	Sand	Ripples	Low	Sand			None
108	9	Plain	Sand	Ripples	Low	Sand			None
108	10	Plain	Sand	Ripples	Low	Sand			None
108	11	Plain	Sand	Ripples	Low	Sand			None
108	12	Plain	Sand	Ripples	Low	Sand			None
108	13	Plain	Sand	Scattered rubble; Ripples	Low	Sand	Colonized rubble		None
108	14	Plain	Sand	Scattered rubble	Low	Sand	CaCO3 Rubble		None
108	17	Plain	Sand	Scattered boulders; Ripples	Low	Sand	CaCO3 Rock		None
108	18	Plain	Sand	Scattered boulders; Ripples	Low	Sand	CaCO3 Rock		None
108	19	Plain	Sand	Ripples	Low	Sand			None
108	20	Plain; Mound	CaCO3 Rubble; Sand		Low	Sand	Dense Colonized rubble		None
108	21	Mound	CaCO3 Rubble		Low	CCA	Macroalgae	Sand	None

TO W	F R	STRUCTURE	SUBSTR	SUBSTMOD	COMPLEX	COVER1	COVER2	COVER3	CORAL PERCE
108	22	Mound	CaCO3 Rubble		Low	CCA	Macroalgae	Sand	None
108	23	Mound	CaCO3 Rubble		Low	CCA	Macroalgae	Sand	None
108	24	Mound	CaCO3 Rubble		Low	CCA	Macroalgae	Sand	None
108	25	Mound	CaCO3 Rubble		Low	Sand	CCA	Macroalgae	None
108	26	Plain	Sand	Scattered boulders	Low	Sand	CaCO3 Rock		None
108	27	Plain	Sand	Scattered rubble; Ripples	Low	Sand	CaCO3 Rock		None
108	28	Mound	CaCO3 Rubble		Low	CCA	Macroalgae	Sand	None
108	29	Plain	Sand	Ripples	Low	Sand			None
108	30	Plain	Sand	Scattered rubble; Infauna	Low	Sand	CaCO3 Rock		None
108	31	Plain	Sand	Scattered boulders; Ripples; Infauna	Low	Sand	CaCO3 Rock		None
108	32	Plain	Sand	Scattered rubble	Low	Sand	CaCO3 Rock		None
108	33	Plain	Sand	Scattered boulders	Low	Sand	CaCO3 Rock		None
108	34	Plain	Sand	Scattered boulders	Low	Sand	CaCO3 Rock		None
108	37	Plain	Sand	Scattered boulders; infauna	Low	Sand	CCA	Macroalgae	None
108	38	Plain	Sand	Scattered rubble	Low	Sand	CaCO3 Rock		None
109	2	Mound	CaCO3 Rubble		Low	CCA	Sand	Macroalgae	Sparse
109	3	Mound	CaCO3 Rubble		Low	CCA	Sand	Macroalgae	Sparse
109	4	Plain	Sand	Ripples; Scattered boulders	Low	Sand	CCA	Macroalgae	None
109	5	Mound	CaCO3 Rubble		Low	CCA	Macroalgae	Sand	None
109	6	Mound	CaCO3 Rubble		Low	CCA	Macroalgae	Sand	None
109	7	Mound	CaCO3 Rubble		Low	Sand	CCA	Macroalgae	None
109	8	Mound	CaCO3 Rubble		Low	CCA	Macroalgae	Sand	None
109	9	Mound	CaCO3 Rubble		Low	CCA	Macroalgae	Sand	None
109	10	Mound	CaCO3 Rubble		Low	CCA	Macroalgae	Sand	Sparse
109	11	Mound	CaCO3 Rubble		Low	CCA	Macroalgae	Sand	Sparse
109	12	Mound	CaCO3 Rubble		Low	CCA	Macroalgae	Sand	Sparse
109	13	Mound	CaCO3 Rubble		Low	CCA	Macroalgae	Sand	Sparse
109	14	Mound	CaCO3 Rubble		Med	CCA	Macroalgae	Sand	None
109	15	Mound	CaCO3 Rubble		Low	CCA	Macroalgae	Sand	Sparse
109	18	Mound	CaCO3 Rubble		Low	CCA	Macroalgae	Sand	Sparse
109	19	Mound	CaCO3 Rubble		Low	CCA	Macroalgae	Sand	None
109	22	Mound	CaCO3 Rubble		Low	CCA	Macroalgae	Sand	Sparse
109	23	Mound	CaCO3 Rubble		Low	CCA	Macroalgae	Sand	Sparse
109	24	Mound	CaCO3 Rubble		Low	CCA	Macroalgae	Sand	Sparse
109	25	Mound	CaCO3 Rubble		Low	CCA	Macroalgae	Sand	Sparse

TOW	FR	STRUCTURE	SUBSTR	SUBSTMOD	COMPLEX	COVER1	COVER2	COVER3	CORAL PERCE
109	26	Mound	CaCO3 Rock		Med	CCA	Macroalgae	Sand	Sparse
109	27	Mound	CaCO3 Rubble		Med	CCA	Macroalgae	Sand	Sparse
109	28	Mound	CaCO3 Rock		Med	CCA	Macroalgae	Sand	Sparse
109	29	Mound; Plain	CaCO3 Rock; Sand	Ripples	Low	Sand	CCA	Macroalgae	Sparse
109	30	Plain; Mound	Sand; CaCO3 Rock	Ripples	Low	Sand	CCA	Macroalgae	Sparse
109	31	Mound	CaCO3 Rock		Low	CCA	Macroalgae	Sand	Sparse
109	32	Plain	Sand	Scattered boulders; Ripples	Low	Sand	CCA	Macroalgae	Sparse
110	1	Mound	CaCO3 Rock		Med	CCA	Coral	Macroalgae	Moderate
110	2	Mound; Plain	CaCO3 Rock; Sand		Low	Sand	CCA	Coral	Sparse
110	3	Plain	Sand	Scattered boulders; infauna	Low	Sand	CaCO3 Rock		Sparse
110	4	Mound	CaCO3 Rock		Med	CCA	Coral	Sand	Sparse
110	5	Mound	CaCO3 Rock		Med	CCA	Macroalgae	Coral	Sparse
110	6	Mound	CaCO3 Rock		Med	CCA	Macroalgae	Coral	Sparse
110	7	Mound	CaCO3 Rock		Med	CCA	Coral	Macroalgae	Sparse
110	8	Mound	CaCO3 Rock		Med	CCA	Macroalgae	Coral	Sparse
110	9	Plain; Mound	Sand; CaCO3 Rock		Low	Sand	CaCO3 Rock		Sparse
110	10	Mound	CaCO3 Rock		Med	CCA	Macroalgae	Coral	Sparse
110	11	Plain	Sand	Infauna	Low	Sand			None
110	12	Plain	Sand	Infauna	Low	Sand			None
110	13	Plain	Sand	Infauna	Low	Sand			None
110	14	Plain	Sand	Infauna	Low	Sand			None
110	15	Plain	Sand	Infauna	Low	Sand			None
110	16	Mound	CaCO3 Rock	Overhangs	Med	CCA	Macroalgae	Coral	Sparse
110	17	Plain	Sand	Ripples; Infauna	Low	Sand			None
110	18	Plain	Sand	Ripples; Infauna	Low	Sand			None
110	19	Plain	Sand	Ripples; Infauna	Low	Sand			None
110	20	Plain	Sand	Ripples; Infauna; Scattered boulders	Low	Sand			None
110	21	Mound	CaCO3 Rubble		Low	CCA	Sand	Macroalgae	Sparse
110	22	Mound	CaCO3 Rubble		Low	CCA	Sand	Macroalgae	Sparse
110	23	Plain	Sand	Scattered rubble	Low	Sand	CaCO3 Rock		None
110	24	Mound	CaCO3 Rock		Med	CCA	Macroalgae	Sand	Sparse

TOW	FR	STRUCTURE	SUBSTR	SUBSTMOD	COMPLEX	COVER1	COVER2	COVER3	CORAL PERCE
110	25	Mound	CaCO3 Rock	Slope	Med	CCA	Macroalgae	Coral	Sparse
110	26	Mound	CaCO3 Rock	Slope	Low	CCA	Macroalgae	Coral	Sparse
110	27	Mound; Plain	CaCO3 Rock; Sand	Slope	Low	Sand	CCA	Macroalgae	Sparse
110	28	Mound	CaCO3 Rock	Slope	Low	CCA	Sand	Macroalgae	Sparse
110	29	Mound	CaCO3 Rock		Med	CCA	Macroalgae	Coral	Sparse
110	30	Mound	CaCO3 Rubble		Low	CCA	Sand	Macroalgae	Sparse
110	31	Mound	CaCO3 Rubble	Slope	Low	CCA	Macroalgae	Sand	Sparse
110	32	Mound	CaCO3 Rubble		Med	CCA	Macroalgae	Sand	Sparse
110	33	Plain	Sand	Infauna; Scattered boulders	Low	Sand	CaCO3 Rock		None
110	34	Plain	Sand	Scattered boulders	Low	Sand	CaCO3 Rock		None
110	35	Plain	Sand	Scattered boulders; infauna	Low	Sand	CaCO3 Rock		None
110	36	Plain	Sand	Infauna	Low	Sand			None
110	37	Plain	Sand	Scattered boulders; infauna	Low	Sand	CaCO3 Rock		None
110	38	Plain; Mound	CaCO3 Rock; Sand		Med	Sand	CCA	Macroalgae	Sparse
110	39	Plain	Sand	Infauna	Low	Sand			None
110	40	Mound	CaCO3 Rubble		Low	CCA	Macroalgae	Sand	Sparse
110	41	Plain	Sand	Infauna	Low	Sand			None
110	42	Mound	CaCO3 Rubble		Low	CCA	Macroalgae	Sand	Sparse
110	43	Mound	CaCO3 Rubble		Low	CCA	Macroalgae	Sand	Sparse
110	44	Mound	CaCO3 Rubble		Low	Sand	CCA	Macroalgae	Sparse
110	45	Plain	Sand	Scattered boulders	Low	Sand	CCA	Macroalgae	Sparse
110	46	Plain	Sand	Scattered boulders	Low	Sand	CCA	Macroalgae	Sparse
110	47	Plain; Mound	Sand; CaCO3 Rock	Infauna	Low	Sand	CCA	Macroalgae	Sparse
110	48	Mound	CaCO3 Rock		Med	CCA	Macroalgae	Coral	Sparse
110	49	Mound	CaCO3 Rubble	Slope	Med	CCA	Macroalgae	Sand	Sparse
110	50	Plain; Mound	Sand; CaCO3 Rock	Infauna	Low	Sand	CCA	Macroalgae	Sparse
110	51	Mound; Plain	CaCO3 Rubble; Sand	Infauna	Low	Sand	CCA	Macroalgae	Sparse
110	52	Plain; Mound	Sand; CaCO3 Rock	Infauna	Low	Sand	CCA	Macroalgae	Sparse
110	53	Mound; Plain	CaCO3 Rubble; Sand	Infauna	Low	Sand	CCA	Macroalgae	None
110	54	Mound	CaCO3 Rubble		Low	CCA	Macroalgae	Sand	Sparse
110	55	Mound	CaCO3 Rubble		Low	CCA	Macroalgae	Sand	Sparse

TO W	F R	STRUCTURE	SUBSTR	SUBSTMOD	COMPLEX	COVER1	COVER2	COVER3	CORAL PERCE
110	56	Mound; Plain	CaCO3 Rubble; Sand	Slope	Low	Sand	CCA	Macroalgae	Sparse
110	57	Plain	Sand	Ripples; Scattered boulders	Low	Sand	CaCO3 Rock		None
110	58	Plain; Mound	CaCO3 Rubble; Sand		Low	CCA	Sand	Macroalgae	Sparse
110	59	Plain	Sand	Infauna; Scattered boulders	Low	Sand	CCA	Macroalgae	Sparse
110	60	Mound	CaCO3 Rubble		Low	CCA	Macroalgae	Sand	Sparse
110	61	Mound	CaCO3 Rubble		Low	CCA	Sand	Macroalgae	Sparse
110	62	Mound	CaCO3 Rubble	Slope	Low	CCA	Sand	Macroalgae	Sparse
110	63	Mound	CaCO3 Rubble		Low	CCA	Macroalgae	Sand	Sparse
110	64	Mound	CaCO3 Boulders	Slope	Low	CCA	Macroalgae	Sand	Sparse
110	65	Mound	CaCO3 Boulders	Slope	Low	CCA	Macroalgae	Sand	Sparse
110	66	Mound	CaCO3 Boulders	Slope	Med	CCA	Macroalgae	Sand	Sparse
110	67	Mound	CaCO3 Boulders	Slope	Med	CCA	Macroalgae	Sand	Sparse
110	68	Mound	CaCO3 Rubble	Slope	Low	CCA	Macroalgae	Sand	Sparse
110	69	Mound	CaCO3 Rubble	Slope	Low	CCA	Macroalgae	Sand	Sparse
110	70	Mound	CaCO3 Rubble	Slope	Low	CCA	Macroalgae	Coral	Sparse
110	71	Mound	CaCO3 Rubble		Low	CCA	Macroalgae	Sand	Sparse
110	72	Plain	Sand	Infauna; Scattered boulders	Low	Sand	CaCO3 Rock		None
110	73	Plain	Sand	Infauna; Scattered boulders; Ripples	Low	Sand	CaCO3 Rock		None
110	74	Plain	Sand	Ripples; Infauna	Low	Sand			None
110	75	Plain	Sand	Ripples; Infauna	Low	Sand			None
110	76	Mound	CaCO3 Rubble		Low	CCA	Sand	Macroalgae	Sparse
110	77	Plain	Sand	Ripples; Infauna	Low	Sand			None
110	78	Plain	Sand	Infauna; Scattered boulders	Low	Sand	CCA	Macroalgae	None
110	79	Mound	CaCO3 Rubble		Low	CCA	Macroalgae		None
110	80	Plain	Sand	Scattered boulders; infauna	Low	Sand	CaCO3 Rock		None
110	81	Plain	Sand	Ripples; Infauna;	Low	Sand	CaCO3 Rock		None

TOW	FR	STRUCTURE	SUBSTR	SUBSTMOD	COMPLEX	COVER1	COVER2	COVER3	CORAL PERCE
				Scattered rubble					
110	82	Plain	Sand	Scattered boulders; infauna	Low	Sand	CaCO3 Rock		None
110	83	Plain	Sand	Ripples; Infauna; Scattered boulders	Low	Sand	CaCO3 Rock		None
110	84	Mound	CaCO3 Rubble		Low	CCA	Sand	Macroalgae	Sparse
110	85	Plain	Sand	Infauna	Low	Sand			None
110	86	Plain	Sand	Infauna; Ripples	Low	Sand			None
110	87	Mound	CaCO3 Rubble	Slope	Low	CCA	Macroalgae	Sand	Sparse
110	88	Mound	CaCO3 Rubble	Slope	Low	CCA	Macroalgae	Sand	Sparse
110	89	Mound	CaCO3 Rubble	Slope	Low	CCA	Macroalgae	Sand	Sparse
110	90	Mound	CaCO3 Rubble		Low	CCA	Macroalgae	Sand	Sparse
110	91	Mound	CaCO3 Rubble		Low	CCA	Macroalgae	Sand	Sparse
110	92	Mound	CaCO3 Boulders		Med	CCA	Macroalgae	Sand	Sparse
110	93	Mound	CaCO3 Rock	Slope	Med	CCA	Macroalgae	Sand	Sparse
110	94	Mound	CaCO3 Rubble		Low	CCA	Macroalgae	Sand	Sparse
110	95	Mound	CaCO3 Rubble		Low	CCA	Macroalgae	Sand	Sparse
110	96	Mound	CaCO3 Rubble		Low	CCA	Macroalgae	Sand	Sparse
111	1	Mound	CaCO3 Rubble		Low	CCA	Macroalgae	Coral	Sparse
111	2	Mound	CaCO3 Rubble		Med	CCA	Macroalgae	Coral	Sparse
111	3	Mound	CaCO3 Rubble		Low	CCA	Macroalgae	Coral	Sparse
111	4	Mound; Plain	CaCO3 Rubble; Sand	Ripples	Low	Sand	CCA	Macroalgae	Sparse
111	5	Mound	CaCO3 Rock		Low	CCA	Macroalgae	Coral	Moderate
111	6	Mound; Plain	CaCO3 Rock; Sand	Slope	Low	Sand	CCA	Macroalgae	Sparse
111	7	Mound; Plain	CaCO3 Rock; Sand		Low	CCA	Macroalgae	Sand	Sparse
111	8	Plain	Sand	Ripples	Low	Sand			None
111	9	Plain; Mound	Sand; CaCO3 Rock	Ripples	Low	Sand	CaCO3 Rock		None
111	10	Plain	Sand	Ripples; Scattered boulders	Low	Sand	CaCO3 Rock		None
111	11	Mound	CaCO3 Rock		Med	CCA	Coral	Macroalgae	Moderate
111	12	Plain	Sand	Ripples; Infauna; Scattered boulders	Low	Sand	CCA	Coral	Sparse

TOW	FR	STRUCTURE	SUBSTR	SUBSTMOD	COMPLEX	COVER1	COVER2	COVER3	CORAL PERCE
111	13	Plain	Sand	Ripples; Infauna; Scattered boulders	Low	Sand	CCA	Coral	Sparse
111	14	Plain	Sand	Ripples; Infauna	Low	Sand			None
111	15	Plain	Sand	Ripples; Infauna	Low	Sand			None
111	16	Plain	Sand	Ripples; Infauna	Low	Sand			None
111	17	Plain	Sand	Ripples; Infauna	Low	Sand			None
111	18	Mound	CaCO3 Rock		Low	CCA	Coral	Sand	Sparse
111	19	Plain	Sand	Ripples; Infauna	Low	Sand			None
111	20	Plain	Sand	Ripples; Infauna	Low	Sand			None
111	21	Plain	Sand	Ripples; Infauna; Scattered boulders	Low	Sand	CCA	Coral	Sparse
111	22	Mound; Plain	CaCO3 Rock; Sand	Ripples	Low	Sand	CCA	Coral	Sparse
111	23	Plain; Mound	Sand; CaCO3 Rock		Low	Sand	CCA	Coral	Sparse
111	24	Plain	Sand	Infauna	Low	Sand			None
111	25	Plain	Sand	Ripples; Infauna; Scattered boulders	Low	Sand	CaCO3 Rock		None
111	26	Plain	Sand	Scattered boulders	High	Sand	CCA	Macroalgae	Sparse
111	27	Plain	Sand	Infauna	Low	Sand			None
111	28	Plain	Sand	Infauna; Scattered boulders	Low	Sand	CaCO3 Rock		Unknown
111	29	Plain	Sand	Infauna	Low	Sand			None
111	30	Plain	Sand	Infauna	Low	Sand			None
111	31	Plain	Sand	Scattered boulders	Low	Sand	CaCO3 Rock		None
111	32	Plain	Sand	Scattered boulders	Low	Sand	CaCO3 Rock		None
111	33	Plain	Sand		Low	Sand			None

TOW	FR	STRUCTURE	SUBSTR	SUBSTMOD	COMPLEX	COVER1	COVER2	COVER3	CORAL PERCE
112	1	Plain	Sand	Infauna	Low	Sand			None
112	2	Plain	Sand	Infauna	Low	Sand			None
112	3	Plain	Sand	Infauna	Low	Sand			None
112	4	Plain	Sand	Infauna	Low	Sand			None
112	5	Plain	Sand	Infauna	Low	Sand			None
112	6	Mound; Plain	CaCO3 Rock; Sand		Med	Sand	CCA	Coral	Sparse
112	7	Plain	Sand	Scattered boulders	Low	Sand	CCA	Coral	Sparse
112	8	Plain	Sand	Infauna	Low	Sand			None
112	9	Plain	Sand	Infauna	Low	Sand			None
112	10	Plain	Sand	Infauna; Scattered boulders	Low	Sand	CCA	Coral	Sparse
112	11	Plain	Sand	Scattered boulders	Low	Sand	CCA	Coral	Sparse
112	12	Plain	Sand	Sand	Low	Sand	CCA	Coral	Sparse
112	13	Plain; Mound	Sand; CaCO3 Rock	Infauna	Low	Sand	CCA	Coral	Sparse
112	14	Plain	Sand	Infauna; Scattered boulders	Low	Sand	CaCO3 Rock		Unknown
112	15	Plain; Mound	Sand; CaCO3 Rock	Infauna	Low	Sand	CCA	Coral	Sparse
112	16	Plain	Sand	Infauna; Scattered boulders	Low	Sand	CCA	Coral	Sparse
112	17	Plain	Sand	Infauna; Scattered boulders	Low	Sand	CCA	Coral	Sparse
112	18	Plain	Sand	Infauna; Scattered boulders	Low	Sand	CaCO3 Rock		Unknown
113	1	Mound	CaCO3 Rock		Low	CCA	Sand	Coral	Sparse
113	2	Patch Reefs	CaCO3 Rock; Sand	Ripples	Med	Sand	CCA	Coral	Sparse
113	3	Patch Reefs	CaCO3 Rock; Sand	Ripples	Med	Sand	CCA	Coral	Sparse
113	4	Patch Reefs	CaCO3 Rock; Sand	Ripples	Med	Sand	CCA	Coral	Sparse
113	5	Plain	Sand	Ripples	Low	Sand			None
113	6	Plain	Sand	Ripples; Adjacent Reef	Low	Sand	CaCO3 Rock		Unknown
113	7	Patch Reefs	CaCO3 Rock		High	CCA	Coral	Macroalgae	Sparse

TOW	FR	STRUCTURE	SUBSTR	SUBSTMOD	COMPLEX	COVER1	COVER2	COVER3	CORALPERCE
113	8	Patch Reefs	Sand; CaCO3 Rock	Ripples	Med	Sand	CCA	Coral	Sparse
113	9	Patch Reefs	Sand; CaCO3 Rock	Ripples	Med	Sand	CCA	Coral	Sparse
113	10	Plain	Sand	Ripples; Adjacent Reef	Low	Sand	CaCO3 Rock		None
113	11	Plain	Sand	Ripples; Adjacent Reef	Low	Sand	CaCO3 Rock		Sparse
113	12	Patch Reefs	CaCO3 Rock; Sand	Ripples	Med	CCA	Sand	Coral	Sparse
113	13	Patch Reefs	CaCO3 Rock; Sand	Ripples	Med	CCA	Sand	Coral	Sparse
113	14	Plain	Sand	Ripples	Low	Sand			None
113	15	Patch Reefs	Sand; CaCO3 Rock	Ripples	Med	Sand	CCA	Coral	Sparse
113	16	Patch Reefs	Sand; CaCO3 Rock	Ripples	Med	Sand	CCA	Coral	Sparse
113	17	Patch Reefs	Sand; CaCO3 Rock	Ripples	Med	Sand	CCA	Coral	Sparse
113	18	Mound	CaCO3 Rock		Med	CCA	Coral	Sand	Sparse
113	19	Patch Reefs	Sand; CaCO3 Rock	Ripples	Med	Sand	CCA	Coral	Sparse
113	20	Patch Reefs	Sand; CaCO3 Rock	Ripples	High	Sand	CCA	Coral	Sparse
113	21	Patch Reefs	Sand; CaCO3 Rock	Ripples	Med	Sand	CCA	Coral	Sparse
113	22	Patch Reefs	Sand; CaCO3 Rock	Ripples	Med	Sand	CCA	Coral	Sparse
113	23	Patch Reefs	Sand; CaCO3 Rock	Ripples	Med	Sand	CCA	Coral	None
113	24	Patch Reefs	Sand; CaCO3 Rock	Ripples	Med	Sand	CCA	Coral	Sparse
113	25	Mound	CaCO3 Rock		Low	CCA	Sand	Coral	Sparse
113	26	Patch Reefs	Sand; CaCO3 Rock	Ripples	Med	Sand	CCA	Coral	Sparse
114	1		Sand	Infauna	Low	Sand		None	
114	2	Plain	Sand	Infauna	Low	Sand			
114	3	Plain	Sand	Infauna	Low	Sand			
114	4	Plain	Sand	Infauna; Adjacent Reef	Low	Sand	CCA	Macroalgae	
114	5	Mound	CaCO3 Rock	Overhangs	Med	CCA	Macroalgae	Sand	
114	6	Plain	Sand	Infauna; Adjacent Reef	Low	Sand	Macroalgae		
114	7	Plain	Sand	Infauna; Scattered	Low	Sand	Macroalgae		

TOW	FR	STRUCTURE	SUBSTR	SUBSTMOD	COMPLEX	COVER1	COVER2	COVER3	CORAL PERCE
				boulders					
114	8	Plain	Sand	Infauna	Low	Sand			
114	9	Plain	Sand	Infauna; Adjacent Reef	Low	Sand	CCA	Macroalgae	
114	10	Mound	CaCO3 Rock		Low	Macroalgae	CCA	Sand	
114	11	Mound	CaCO3 Rock	Overhangs	Med	Macroalgae	CCA	Sand	
114	12	Mound	CaCO3 Rock	Overhangs	Med	Macroalgae	CCA	Sand	
114	13	Mound	CaCO3 Rock	Overhangs	Med	Macroalgae	CCA	Sand	
114	14	Mound	CaCO3 Rock	Overhangs	Med	Macroalgae	CCA	Sand	
114	15	Mound	CaCO3 Rock	Slope; Overhangs	Low	Macroalgae	CCA	Sand	
114	16	Mound	CaCO3 Rock	Slope	Low	Macroalgae	CCA	Sand	
114	17	Mound	CaCO3 Rock	Slope	Low	Macroalgae	CCA	Sand	
114	18	Mound	CaCO3 Rock		Low	Macroalgae	CCA	Sand	
114	19	Mound	CaCO3 Rock	Slope; Overhangs	Low	Macroalgae	CCA	Sand	
114	20	Plain	Sand		Low	Sand			
114	21	Plain	Sand		Low	Sand			
114	22	Plain	Sand		Low	Sand			
114	23	Plain	Sand		Low	Sand			
114	24	Plain	Sand	Infauna	Low	Sand			
114	25	Plain	Sand	Infauna	Low	Sand			
114	26	Plain	Sand	Infauna	Low	Sand			
114	27	Plain	Sand	Infauna	Low	Sand			

Table A-05. Ranges used for LFH calculations.

Grid	LFH0	LFH1	LFH2	LFH3
05 m	300.0	1.5	0.25	0.35
10 m	300.0	1.5	0.25	0.35
20 m	300.0	2.5	0.50	0.50

Table A-06. LFH class prototypes from 10 random training samples (comma separated form).

ClassRand10,row,E,N,LFH0_0,LFH0_1,LFH0_2,LFH0_3,LFH0_4,LFH0_5,LFH0_6,LFH0_7,LFH1_0,LFH1_1,LFH1_2,LFH1_3,LFH1_4,LFH1_5,LFH1_6,LFH1_7,LFH2_0,LFH2_1,LFH2_2,LFH2_3,LFH2_4,LFH2_5,LFH2_6,LFH2_7,LFH3_0,LFH3_1,LFH3_2,LFH3_3,LFH3_4,LFH3_5,LFH3_6,LFH3_7

1,.,.,.,1,0,0,0,0,0,0,0,1,0,0,0,0,0,0,0,1,0,0,0,0,0,0,0,1,0,0,0,0,0,0,0

2,69,358593.8,1681714,1,0,0,0,0,0,0,0,1,0,0,0,0,0,0,0,0.91,0.09,0,0,0,0,0,0,1,0,0,0,0,0,0,0

3,73,359793.8,1682714,1,0,0,0,0,0,0,0,1,0,0,0,0,0,0,0,0.54,0.36,0.1,0,0,0,0,0,0.85,0.15,0,0,0,0,0,0

4,83,360693.8,1683514,1,0,0,0,0,0,0,0,1,0,0,0,0,0,0,0,0.68,0.28,0.03,0.01,0,0,0,0,0.81,0.18,0.01,0,0,0,0,0

5,52,356693.8,1680114,1,0,0,0,0,0,0,0,0.53,0.47,0,0,0,0,0,0,0.69,0.26,0.05,0,0,0,0,0,0.78,0.22,0,0,0,0,0,0

6,86,356093.8,1684014,0.02,0.98,0,0,0,0,0,0,0.37,0.41,0.2,0.02,0,0,0,0,0.1,0.31,0.16,0.26,0.1,0.05,0.01,0.01,0.41,0.43,0.15,0.01,0,0,0,0

7,57,352993.8,1680614,1,0,0,0,0,0,0,0,0.32,0.5,0.17,0.01,0,0,0,0,0.12,0.3,0.31,0.12,0.09,0.03,0.01,0.02,0.47,0.44,0.09,0,0,0,0,0

8,26,357493.8,1677814,0,1,0,0,0,0,0,0,0.31,0.33,0.25,0.11,0,0,0,0,0.03,0.15,0.16,0.2,0.11,0.1,0.12,0.13,0.24,0.36,0.25,0.1,0.04,0,0,0.01

9,51,353793.8,1680014,0,1,0,0,0,0,0,0,0.07,0.12,0.26,0.49,0.06,0,0,0,0.2,0.28,0.35,0.08,0.05,0.04,0,0,0.14,0.33,0.26,0.18,0.06,0.03,0,0

10,0,358493.8,1672114,0,0,1,0,0,0,0,0,0,0,0.02,0.63,0.32,0.03,0,0,0.07,0.12,0.23,0.2,0.16,0.05,0.07,0.1,0.01,0.16,0.19,0.2,0.19,0.08,0.08,0.09

11,17,351793.8,1676714,0,0,0,0,0.09,0.91,0,0,0,0,0,0,0,0.03,0.08,0.89,0.01,0.03,0.06,0.05,0.14,0.05,0.03,0.63,0.01,0.02,0.06,0.03,0.07,0.15,0.06,0.6

Table A-07. LFH class prototypes from video ground-truth (vgt) training samples. Mean LFH feature vectors for each level of the video data variable substrate (SUBSTR) (comma separated format).

SUBSTR,NumRows,LFH0_0,LFH0_1,LFH0_2,LFH0_3,LFH0_4,LFH0_5,LFH0_6,LFH0_7,LFH1_0,LFH1_1,LFH1_2,LFH1_3,LFH1_4,LFH1_5,LFH1_6,LFH1_7,LFH2_0,LFH2_1,LFH2_2,LFH2_3,LFH2_4,LFH2_5,LFH2_6,LFH2_7,LFH3_0,LFH3_1,LFH3_2,LFH3_3,LFH3_4,LFH3_5,LFH3_6,LFH3_7

CaCO3 Boulders,

5,1,0,0,0,0,0,0,0,0.218,0.424,0.322,0.036,0,0,0,0,0.348,0.326,0.172,0.084,0.044,0.012,0.014,0,0.34,0.53,0.13,0,0,0,0,0

CaCO3 Rock,

79,0.975569620253165,0.0244303797468354,0,0,0,0,0,0,0.567435443037974,0.255935443037975,0.103717721518987,0.0429113924050633,0.0241772151898734,0.00582278481012658,0,0,0.356424050632912,0.290059493670886,0.172150632911392,0.0919924050632911,0.0577810126582279,0.0209329113924051,0.00635569620253165,0.00430379746835443,0.626824050632911,0.25896582278481,0.0777012658227848,0.0297873417721519,0.00583670886075949,0.000886075949367089,0,0

CaCO3 Rock and Sand,

20,1,0,0,0,0,0,0,0,0.8465,0.1135,0.0365,0.0035,0,0,0,0,0.4885,0.2855,0.123,0.0575,0.03,0.012,0.003,0.0005,0.785,0.1875,0.027,0.0005,0,0,0,0

CaCO3 Rubble,

61,1,0,0,0,0,0,0,0,0.532777049180328,0.325747540983607,0.12,0.0191803278688525,0.00229508196721312,0,0,0,0.371993442622951,0.314219672131148,0.176234426229508,0.071316393442623,0.0388573770491803,0.0139344262295082,0.010655737704918,0.00278688524590164,0.623422950819672,0.3269,0.0445950819672131,0.0039344262295082,0.00114754098360656,0,0,0

CaCO3 Rubble and Sand,

6,1,0,0,0,0,0,0,0,0.498333333333333,0.32,0.133333333333333,0.0483333333333333,0,0,0,0,0.153333333333333,0.278333333333333,0.268333333333333,0.151666666666667,0.085,0.045,0.015,0.00333333333333333,0.54,0.37

3333333333333,0.08,0.00666666666666667,0,0,0,0

Sand,

178,0.957752808988764,0.042247191011236,0,0,0,0,0,0,0.757729213483146,0.140466292134831,0.0714943820224719,0.0236247191011236,0.00595505617977528,0.000730337078651685,0,0,0.533194382022472,0.24216404494382,0.11381797752809,0.0571393258426966,0.0346601123595505,0.0121898876404494,0.00488426966292135,0.00194887640449438,0.754615168539325,0.187206741573034,0.0454696629213483,0.00940337078651685,0.0030247191011236,0.000280898876404494,0,0

Sand and CaCO3 Rock,

23,1,0,0,0,0,0,0,0,0.839130434782609,0.118260869565217,0.0404347826086957,0.00217391304347826,0,0,0,0,0.349565217391304,0.355652173913043,0.17,0.0656521739130435,0.0356521739130435,0.0173913043478261,0.00521739130434783,0.000869565217391304,0.675217391304348,0.292173913043478,0.03,0.00217391304347826,0.000434782608695652,0,0,0

Table A-08. Training samples from combined set of random, arbitrary, and video ground-truth (vgt) data.

Set,Name,E,N

General,zero,.,.

Random,Rand01,358593.8,1681714

Random,Rand02,359793.8,1682714

Random,Rand03,360693.8,1683514

Random,Rand04,356693.8,1680114

Random,Rand05,356093.8,1684014

Random,Rand06,352993.8,1680614

Random,Rand07,357493.8,1677814

Random,Rand08,353793.8,1680014

Random,Rand09,358493.8,1672114

Random,Rand10,351793.8,1676714

Arbitrary,ArbReef1,357500.2814914,1679920.4613487

Arbitrary,ArbReef2,357027.48146701,1680473.2736849

Arbitrary,ArbX01,357145.02682692,1679036.2525646

Arbitrary,ArbX02,358062.1133973,1678715.0395019

Arbitrary,ArbX03,357093.8,1677814

Arbitrary,ArbX04,356172.07711519,1679213.1525122

Arbitrary,BroadReefTop,352570.14122744,1678713.6955527

Arbitrary,BroadReefTop,352798.31669693,1679347.5163012

Arbitrary,ChannelBottomNoisy,357893.8,1684114

Arbitrary,ChannelBottomNoisy,357893.8,1684014

Arbitrary,DeepChannelBank,356693.8,1682514

Arbitrary,DeepChannelBank,356793.8,1683314

Arbitrary,DeepChannelBank,356993.8,1680814

Arbitrary,DeepChannelBottom,356293.8,1680914

Arbitrary,DeepChannelBottom,356493.8,1681214

Arbitrary,DredgedChannel,360895.06324139,1683996.7310255

Arbitrary,DredgedChannel,360763.12166466,1683989.1915068

Arbitrary,DredgedChannel,360974.22818743,1683992.9612661

Arbitrary,Heterogeneous,358869.64620034,1682150.1786384

Arbitrary,LargeMoundTop,359078.70618821,1680618.7506155

Arbitrary,MoundsCommon,359225.92884195,1678975.7341615

Arbitrary,MoundsCommon,359090.92625038,1679278.3261771

Arbitrary,MoundsCommon,359300.41303041,1678789.5236904

Arbitrary,NEhighfreqrough,359779.21447816,1683548.1296646

Arbitrary,NElargelumps,360529.39658587,1683751.6966687

Arbitrary,Ngradualslope,356093.8,1684414

Arbitrary,PeakReef,358583.50271651,1679129.3578002

Arbitrary,ReefBorderedSediment,353151.35485389,1680011.5576231

Arbitrary,ReefEdgeW,351979.54198335,1680390.5013017

Arbitrary,ReefRidgeSE,358932.6473499,1679045.5630882

Arbitrary,ReefRidgeSE,358634.71059607,1679445.9156012

Arbitrary,ReefRidgeSE,358718.50530809,1679217.807774

Arbitrary,ReefRidgeSE,359235.23936551,1678612.6237428

Arbitrary,SmoothSedimented,359140.61724677,1682354.623859

Arbitrary,SmoothSedimented,356451.3928219,1678831.4210464

Arbitrary,SpurGrooveLike,355764.42078613,1684467.9509424

Video,CaCO3 Rock,356972.033,1679260.21

Video,Sand,356972.089,1679269.44

Video,Sand,356972.157,1679280.5

Video,Sand,356972.213,1679289.72

Video,CaCO3 Rock,356970.442,1679298.95

Video,CaCO3 Rock,356970.499,1679308.17

Video,CaCO3 Rock,356970.544,1679315.54

Video,CaCO3 Rock,356970.6,1679324.77

Video,CaCO3 Rock,356970.667,1679335.83

Video,CaCO3 Rock,356970.712,1679343.2

Video,CaCO3 Rock,356970.779,1679354.26

Video,CaCO3 Rock,356968.986,1679359.8

Video,CaCO3 Rock,356970.869,1679369.02

Video,CaCO3 Rock,356967.38,1679378.26

Video,CaCO3 Rock,356967.436,1679387.47

Video,Sand,356965.654,1679394.86

Video,Sand,356963.884,1679404.09

Video,Sand,356963.94,1679413.32

Video,Sand,356962.277,1679422.54

Video,Sand,356960.507,1679431.77

Video,CaCO3 Rock,356958.737,1679441.01

Video,CaCO3 Rock,356957.063,1679448.39

Video,CaCO3 Rock,356957.119,1679457.61

Video,CaCO3 Rock,356955.348,1679466.84

Video,CaCO3 Rock,358681.925,1679231.43

Video,CaCO3 Rock,358683.707,1679224.04

Video,CaCO3 Rock,358683.651,1679214.83

Video,CaCO3 Rock,358685.445,1679209.28

Video,CaCO3 Rock,358683.563,1679200.07

Video,CaCO3 Rock,358685.334,1679190.84

Video,CaCO3 Rock,358683.452,1679181.64

Video,CaCO3 Rock,358685.234,1679174.25

Video,Sand,358683.374,1679168.73

Video,CaCO3 Rock,358683.33,1679161.35

Video,CaCO3 Rock,358685.123,1679155.8

Video,CaCO3 Rock,358685.09,1679150.27

Video,Sand,358685.034,1679141.06

Video,Sand,358686.709,1679133.67

Video,CaCO3 Rock,358684.957,1679128.15

Video,Sand,358686.642,1679122.61

Video,Sand,358686.598,1679115.24

Video,Sand,358686.565,1679109.71

Video,Sand,358688.358,1679104.16

Video,CaCO3 Rock,358686.498,1679098.64

Video,CaCO3 Rock,358686.46,1679092.19

Video,Sand,358686.421,1679085.73

Video,CaCO3 Rock; Sand,358686.387,1679080.2

Video,Sand,358686.354,1679074.67

Video,Sand,358686.321,1679069.14

Video,Sand,358686.287,1679063.61

Video,Sand,358686.254,1679058.07

Video,Sand,358686.21,1679050.7

Video,Sand; CaCO3 Rock,358688.003,1679045.15

Video,CaCO3 Rock,358687.97,1679039.62

Video,Sand; CaCO3 Rock,358686.099,1679032.26

Video,Sand,358961.994,1679941.5

Video,Sand,358965.495,1679934.1

Video,CaCO3 Rock,358969.093,1679924.86

Video,CaCO3 Rock,358970.756,1679915.64

Video,Sand,358972.527,1679906.4

Video,Sand,358972.472,1679897.18

Video,CaCO3 Rock; Sand,358972.417,1679887.97

Video,Sand,358970.535,1679878.75

Video,Sand,358968.75,1679867.7

Video,CaCO3 Rock,358966.868,1679858.5

Video,CaCO3 Rock,358964.975,1679847.44

Video,CaCO3 Rock; Sand,358961.374,1679838.25

Video,Sand,358959.503,1679830.88

Video,Sand,358955.903,1679821.69

Video,Sand,358952.313,1679814.33

Video,Sand,358948.594,1679803.29

Video,Sand,358946.819,1679794.08

Video,CaCO3 Rock; Sand,358943.122,1679786.73

Video,Sand,358939.521,1679777.53

Video,Sand,358935.921,1679768.33

Video,Sand,358930.505,1679760.99

Video,CaCO3 Rock,358393.619,1680116.41

Video,CaCO3 Rock,358395.434,1680114.55

Video,CaCO3 Rock,358397.153,1680114.54

Video,CaCO3 Rock,358398.98,1680114.53

Video,CaCO3 Rock,358398.98,1680114.53

Video,CaCO3 Rock; Sand,358402.514,1680112.67

Video,Sand,358404.34,1680112.66

Video,Sand,358402.514,1680112.67

Video,Sand,358406.156,1680110.8

Video,Sand,358406.167,1680112.65

Video,Sand,358407.886,1680112.64

Video,Sand,358413.268,1680114.44

Video,CaCO3 Rock,358418.651,1680116.26

Video,CaCO3 Rock,358425.872,1680119.9

Video,CaCO3 Rock; Sand,358434.811,1680123.54

Video,Sand,358440.194,1680125.34

Video,Sand,358447.403,1680127.15

Video,Sand,358452.786,1680128.96

Video,CaCO3 Rubble,358458.158,1680128.93

Video,Sand,358465.367,1680130.72

Video,Sand,358470.75,1680132.54

Video,Sand,358476.133,1680134.35

Video,Sand,358481.505,1680134.32

Video,Sand,358486.887,1680136.13

Video,CaCO3 Rock,358493.978,1680136.08

Video,CaCO3 Rock; Sand,358499.35,1680136.05

Video,Sand,358502.992,1680134.19

Video,Sand,358508.363,1680134.16

Video,Sand,358513.735,1680134.13

Video,Sand,358517.28,1680134.11

Video,Sand,358522.652,1680134.07

Video,Sand,358528.013,1680132.19

Video,Sand,358531.558,1680132.17

Video,Sand,358535.2,1680130.3

Video,Sand,358538.745,1680130.28

Video,Sand,359006.054,1681606.3

Video,Sand,359002.39,1681604.48

Video,Sand,358998.834,1681602.66

Video,Sand,358995.267,1681598.99

Video,Sand,358991.592,1681595.33

Video,Sand,358986.21,1681593.51

Video,Sand,358984.457,1681587.99

Video,Sand,358979.075,1681586.19

Video,Sand,358973.67,1681580.69

Video,Sand,358968.266,1681575.19

Video,Sand,358966.395,1681567.82

Video,Sand,358962.795,1681558.62

Video,Sand,358960.913,1681549.41

Video,Sand,358957.323,1681542.06

Video,Sand,358948.144,1681516.29

Video,Sand,358944.555,1681508.95

Video,Sand,358940.954,1681499.74

Video,CaCO3 Rubble; Sand,358939.083,1681492.39

Video,CaCO3 Rubble,358935.483,1681483.18

Video,CaCO3 Rubble,358933.601,1681473.98

Video,CaCO3 Rubble,358930.012,1681466.62

Video,CaCO3 Rubble,358928.141,1681459.26

Video,CaCO3 Rubble,358924.54,1681450.05

Video,Sand,358922.659,1681440.85

Video,Sand,358920.788,1681433.48

Video,CaCO3 Rubble,358917.187,1681424.29

Video,Sand,358911.761,1681415.1

Video,Sand,358909.879,1681405.89

Video,Sand,358904.452,1681396.71

Video,Sand,358899.025,1681387.52

Video,Sand,358895.424,1681378.32

Video,Sand,358889.998,1681369.13

Video,Sand,358875.543,1681341.56

Video,Sand,358870.116,1681332.38

Video,CaCO3 Rubble,359462.922,1679859.21

Video,CaCO3 Rubble,359455.69,1679853.72

Video,Sand,359446.74,1679848.24

Video,CaCO3 Rubble,359441.335,1679842.74

Video,CaCO3 Rubble,359435.93,1679837.24

Video,CaCO3 Rubble,359428.688,1679829.92

Video,CaCO3 Rubble,359421.467,1679826.26

Video,CaCO3 Rubble,359416.052,1679818.93

Video,CaCO3 Rubble,359410.636,1679811.58

Video,CaCO3 Rubble,359405.209,1679802.4

Video,CaCO3 Rubble,359401.619,1679795.04

Video,CaCO3 Rubble,359396.192,1679785.86

Video,CaCO3 Rubble,359390.765,1679776.66

Video,CaCO3 Rubble,359385.36,1679771.16

Video,CaCO3 Rubble,359374.473,1679747.26

Video,CaCO3 Rubble,359370.883,1679739.91

Video,CaCO3 Rubble,359363.52,1679712.29

Video,CaCO3 Rubble,359359.93,1679704.93

Video,CaCO3 Rubble,359356.233,1679697.59

Video,CaCO3 Rubble,359352.621,1679686.54

Video,CaCO3 Rock,359349.032,1679679.19

Video,CaCO3 Rubble,359345.324,1679669.99

Video,CaCO3 Rock,359341.734,1679662.64

Video,CaCO3 Rock; Sand,359339.875,1679657.12

Video,Sand; CaCO3 Rock,359336.285,1679649.76

Video,CaCO3 Rock,359334.403,1679640.55

Video,Sand,359330.803,1679631.36

Video,CaCO3 Rock,357464.829,1680509.25

Video,CaCO3 Rock; Sand,357473.865,1680511.05

Video,Sand,357482.793,1680512.83

Video,CaCO3 Rock,357491.721,1680514.62

Video,CaCO3 Rock,357502.475,1680516.41

Video,CaCO3 Rock,357513.23,1680518.18

Video,CaCO3 Rock,357523.973,1680518.11

Video,CaCO3 Rock,357534.728,1680519.89

Video,Sand; CaCO3 Rock,357545.471,1680519.83

Video,CaCO3 Rock,357556.226,1680521.61

Video,Sand,357566.969,1680521.54

Video,Sand,357579.55,1680523.3

Video,Sand,357590.305,1680525.09

Video,Sand,357602.885,1680526.86

Video,Sand,357613.64,1680528.63

Video,CaCO3 Rock,357624.406,1680532.26

Video,Sand,357636.89,1680535.87

Video,Sand,357645.948,1680541.35

Video,Sand,357656.736,1680548.66

Video,Sand,357671.07,1680555.94

Video,CaCO3 Rubble,357685.403,1680563.23

Video,CaCO3 Rubble,357698.006,1680568.69

Video,Sand,357708.805,1680577.84

Video,CaCO3 Rock,357719.582,1680583.31

Video,CaCO3 Rock,357730.37,1680590.62

Video,CaCO3 Rock,357741.147,1680596.09

Video,CaCO3 Rock; Sand,357751.924,1680601.55

Video,CaCO3 Rock,357760.886,1680608.88

Video,CaCO3 Rock,357769.944,1680614.36

Video,CaCO3 Rubble,357778.894,1680619.83

Video,CaCO3 Rubble,357789.671,1680625.3

Video,CaCO3 Rubble,357800.448,1680630.77

Video,Sand,357809.409,1680638.08

Video,Sand,357820.186,1680643.55

Video,Sand,357830.952,1680647.18

Video,Sand,357840.01,1680652.65

Video,Sand,357850.775,1680656.27

Video,CaCO3 Rock; Sand,357859.726,1680661.75

Video,Sand,357872.317,1680665.36

Video,CaCO3 Rubble,357883.072,1680667.14

Video,Sand,357892.011,1680670.77

Video,CaCO3 Rubble,357902.777,1680674.4

Video,CaCO3 Rubble,357911.694,1680674.35

Video,CaCO3 Rubble,357920.74,1680677.98

Video,Sand,357931.495,1680679.76

Video,Sand,357942.249,1680681.53

Video,Sand; CaCO3 Rock,357951.177,1680683.32

Video,CaCO3 Rock,357960.105,1680685.12

Video,CaCO3 Rubble,357967.314,1680686.91

Video,Sand; CaCO3 Rock,357976.243,1680688.7

Video,CaCO3 Rubble; Sand,357985.267,1680688.65

Video,Sand; CaCO3 Rock,357997.729,1680688.57

Video,CaCO3 Rubble; Sand,358010.299,1680688.5

Video,CaCO3 Rubble,358021.053,1680690.28

Video,CaCO3 Rubble,358029.97,1680690.23

Video,CaCO3 Rubble; Sand,358038.983,1680688.32

Video,Sand,358047.9,1680688.27

Video,CaCO3 Rubble; Sand,358053.261,1680686.39

Video,Sand,358060.459,1680686.35

Video,CaCO3 Rubble,358064.015,1680688.17

Video,CaCO3 Rubble,358069.387,1680688.14

Video,CaCO3 Rubble,358074.758,1680688.11

Video,CaCO3 Rubble,358080.13,1680688.08

Video,CaCO3 Boulders,358085.501,1680688.04

Video,CaCO3 Boulders,358090.884,1680689.86

Video,CaCO3 Boulders,358098.071,1680687.97

Video,CaCO3 Boulders,358108.814,1680687.9

Video,CaCO3 Rubble,358117.731,1680687.85

Video,CaCO3 Rubble,358128.452,1680684.1

Video,CaCO3 Rubble,358142.696,1680676.63

Video,CaCO3 Rubble,358155.21,1680667.34

Video,Sand,358167.735,1680659.89

Video,Sand,358180.164,1680654.28

Video,Sand,358196.223,1680644.97

Video,Sand,358212.293,1680637.49

Video,CaCO3 Rubble,358226.634,1680628.19

Video,Sand,358242.715,1680622.56

Video,Sand,358255.122,1680613.26

Video,CaCO3 Rubble,358269.473,1680605.8

Video,Sand,358283.706,1680596.49

Video,Sand,358296.22,1680587.2

Video,Sand,358310.464,1680579.73

Video,Sand,358322.978,1680570.44

Video,CaCO3 Rubble,358333.677,1680563

Video,Sand,358346.084,1680553.71

Video,Sand,358358.609,1680546.25

Video,CaCO3 Rubble,358369.296,1680536.97

Video,CaCO3 Rubble,358379.984,1680527.69

Video,CaCO3 Rubble,358396.032,1680516.53

Video,CaCO3 Rubble,358412.081,1680505.37

Video,CaCO3 Rubble,358428.129,1680494.21

Video,CaCO3 Boulders,358442.362,1680484.9

Video,CaCO3 Rock,358458.41,1680473.74

Video,CaCO3 Rubble,358470.924,1680464.44

Video,CaCO3 Rubble,358485.157,1680455.14

Video,CaCO3 Rubble,358497.66,1680444

Video,CaCO3 Rubble,358599.254,1679473.48

Video,CaCO3 Rubble,358595.62,1679458.75

Video,CaCO3 Rubble,358588.321,1679442.2

Video,CaCO3 Rubble; Sand,358582.85,1679425.64

Video,CaCO3 Rock,358577.378,1679409.08

Video,CaCO3 Rock; Sand,358570.08,1679392.53

Video,CaCO3 Rock; Sand,358564.608,1679375.97

Video,Sand,358555.601,1679361.26

Video,Sand; CaCO3 Rock,358548.292,1679342.87

Video,Sand,358539.297,1679330.02

Video,CaCO3 Rock,358532.01,1679315.31

Video,Sand,358526.549,1679300.59

Video,Sand,358521.11,1679289.55

Video,Sand,358515.65,1679274.84

Video,Sand,358512.015,1679260.12

Video,Sand,358508.403,1679249.07

Video,Sand,358506.488,1679234.33

Video,CaCO3 Rock,358504.573,1679219.59

Video,Sand,358502.765,1679204.85

Video,Sand,358502.698,1679193.79

Video,Sand,358506.166,1679180.86

Video,CaCO3 Rock; Sand,358506.099,1679169.79

Video,Sand; CaCO3 Rock,358506.021,1679156.88

Video,Sand,358505.933,1679142.14

Video,Sand,358504.017,1679127.4

Video,Sand,358502.209,1679112.65

Video,Sand,358498.457,1679096.08

Video,Sand,358496.649,1679081.34

Video,Sand,358494.733,1679066.61

Video,Sand,358489.273,1679051.88

Video,Sand,358487.357,1679037.14

Video,Sand,358483.712,1679020.57

Video,Sand,358481.796,1679005.84

Video,Sand,359458.904,1678900.4

Video,Sand,359458.805,1678883.8

Video,Sand,359455.16,1678867.23

Video,Sand,359451.526,1678852.49

Video,Sand,359444.251,1678839.64

Video,CaCO3 Rock; Sand,359438.791,1678824.91

Video,Sand,359433.33,1678810.2

Video,Sand,359426.055,1678797.33

Video,Sand,359420.594,1678782.61

Video,Sand,359413.404,1678766.06

Video,Sand,359404.302,1678753.2

Video,Sand,359398.83,1678736.64

Video,Sand; CaCO3 Rock,359389.824,1678721.95

Video,Sand,359382.538,1678707.24

Video,Sand; CaCO3 Rock,359373.532,1678692.54

Video,Sand,359364.526,1678677.85

Video,Sand,359355.424,1678664.99

Video,Sand,359348.244,1678650.28

Video,CaCO3 Rock,360132.061,1682779.67

Video,CaCO3 Rock; Sand,360126.635,1682770.48

Video,CaCO3 Rock; Sand,360123.057,1682764.97

Video,CaCO3 Rock; Sand,360115.804,1682755.8

Video,Sand,360112.204,1682746.6

Video,Sand,360108.615,1682739.24

Video,CaCO3 Rock,360103.2,1682731.9

Video,Sand; CaCO3 Rock,360099.504,1682724.55

Video,Sand; CaCO3 Rock,360094.089,1682717.2

Video,Sand,360090.5,1682709.85

Video,Sand,360085.085,1682702.51

Video,CaCO3 Rock; Sand,360081.474,1682691.47

Video,CaCO3 Rock; Sand,360079.582,1682680.42

Video,Sand,360077.689,1682669.36

Video,Sand; CaCO3 Rock,360074.089,1682660.16

Video,Sand; CaCO3 Rock,360070.478,1682649.12

Video,Sand; CaCO3 Rock,360070.412,1682638.05

Video,CaCO3 Rock,360064.975,1682627.02

Video,Sand; CaCO3 Rock,360061.268,1682617.83

Video,Sand; CaCO3 Rock,360055.831,1682606.8

Video,Sand; CaCO3 Rock,360050.393,1682595.77

Video,Sand; CaCO3 Rock,360044.956,1682584.74

Video,Sand; CaCO3 Rock,360039.519,1682573.7

Video,Sand; CaCO3 Rock,360035.908,1682562.66

Video,CaCO3 Rock,360028.645,1682551.64

Video,Sand; CaCO3 Rock,360023.218,1682542.46

Video,Sand,358377.315,1683341.54

Video,Sand,358375.456,1683336.02

Video,Sand,358373.607,1683332.35

Video,Sand,358373.585,1683328.65

Video,CaCO3 Rock,358371.844,1683324.98

Video,Sand,358368.17,1683321.32

Video,Sand,358366.429,1683317.63

Video,Sand,358362.754,1683313.97

Video,Sand,358359.198,1683312.15

Video,CaCO3 Rock,358355.631,1683308.48

Video,CaCO3 Rock,358351.978,1683308.5

Video,CaCO3 Rock,358346.607,1683308.54

Video,CaCO3 Rock,358343.063,1683308.56

Video,CaCO3 Rock,358335.854,1683306.75

Video,CaCO3 Rock,358330.483,1683306.79

Video,CaCO3 Rock,358325.101,1683304.98

Video,CaCO3 Rock,358319.73,1683305.02

Video,CaCO3 Rock,358312.64,1683305.06

Video,CaCO3 Rock,358305.454,1683306.94

Video,Sand,358298.246,1683305.15

Video,Sand,358291.167,1683307.02

Video,Sand,358283.97,1683307.07

Video,Sand,358276.784,1683308.96

Video,Sand,358267.868,1683309.01

Video,Sand,358260.671,1683309.06

Video,Sand,358253.581,1683309.1

Video,Sand,358246.395,1683310.99

Table A-09. LFH class prototypes (mean LFH feature vectors) for each class of the combined set of random, arbitrary, and video ground-truth (vgt) training samples.

ID,Source,Name,LFH 1,LFH 2,LFH 3,LFH 4,LFH 5,LFH 6,LFH 7,LFH 8,LFH 9,LFH 10,LFH 11,LFH 12,LFH 13,LFH 14,LFH 15,LFH 16,LFH 17,LFH 18,LFH 19,LFH 20,LFH 21,LFH 22,LFH 23,LFH 24,LFH 25,LFH 26,LFH 27,LFH 28,LFH 29,LFH 30,LFH 31,LFH 32

0,General,zero,1,0,0,0,0,0,0,0,1,0,0,0,0,0,0,0,1,0,0,0,0,0,0,0,1,0,0,0,0,0,0,0

1,Random,Rand01 (background1),1,0,0,0,0,0,0,0,1,0,0,0,0,0,0,0,0.91,0.09,0,0,0,0,0,0,1,0,0,0,0,0,0,0

2,Random,Rand02 (background2),1,0,0,0,0,0,0,0,1,0,0,0,0,0,0,0,0.54,0.36,0.1,0,0,0,0,0,0.85,0.15,0,0,0,0,0,0

3,Random,Rand03 (background3),1,0,0,0,0,0,0,0,1,0,0,0,0,0,0,0,0.68,0.28,0.03,0.01,0,0,0,0,0.81,0.18,0.01,0,0,0,0,0

4,Random,Rand04 (background4),1,0,0,0,0,0,0,0,0.53,0.47,0,0,0,0,0,0,0.69,0.26,0.05,0,0,0,0,0,0.78,0.22,0,0,0,0,0,0

5,Random,Rand05 (background5),0.02,0.98,0,0,0,0,0,0,0.37,0.41,0.2,0.02,0,0,0,0,0.1,0.31,0.16,0.26,0.1,0.05,0.01,0.01,0.41,0.43,0.15,0.01,0,0,0,0

6,Random,Rand06 (background6),1,0,0,0,0,0,0,0,0.32,0.5,0.17,0.01,0,0,0,0,0.12,0.3,0.31,0.12,0.09,0.03,0.01,0.02,0.47,0.44,0.09,0,0,0,0,0

7,Random,Rand07 (background7),0,1,0,0,0,0,0,0,0.31,0.33,0.25,0.11,0,0,0,0,0.03,0.15,0.16,0.2,0.11,0.1,0.12,0.13,0.24,0.36,0.25,0.1,0.04,0,0,0.01

8,Random,Rand08 (background8),0,1,0,0,0,0,0,0,0.07,0.12,0.26,0.49,0.06,0,0,0,0.2,0.28,0.35,0.08,0.05,0.04,0,0,0.14,0.33,0.26,0.18,0.06,0.03,0,0

9,Random,Rand09 (background9),0,0,1,0,0,0,0,0,0,0,0.02,0.63,0.32,0.03,0,0,0.07,0.12,0.23,0.2,0.16,0.05,0.07,0.1,0.01,0.16,0.19,0.2,0.19,0.08,0.08,0.09

10,Random,Rand10

(DeepChannelBank),0,0,0,0,0.09,0.91,0,0,0,0,0,0,0,0.03,0.08,0.89,0.01,0.03,0.06,0.05,0.14,0.05,0.03,0.63,0.01,0.02,0.06,0.03,0.07,0.15,0.06,0.6

11,Arbitrary,ChannelBottomNoisy,0,0,0,0,0,1,0,0,0.555,0.445,0,0,0,0,0,0,0.29,0.455,0.205,0.035,0.015,0,0,0,0.435,0.435,0.11,0.02,0,0,0,0

12,Arbitrary,LargeSlopes,0,0.19666667,0.80333333,0,0,0,0,0,0,0,0.22666667,0.52666667,0.12,0.08666667,0.03333333,0.00666667,0.18666667,0.27,0.17,0.10333333,0.05333333,0.03,0.03666667,0.15,0.02,0.18666667,0.34,0.21666667,0.07,0.06666667,0.02333333,0.07666667

13,Arbitrary,DeepChannelBottom,0,0,0,0,0,1,0,0,0.5,0.32,0.175,0.005,0,0,0,0,0.58,0.26,0.115,0.03,0.01,0,0,0.005,0.54,0.25,0.095,0.085,0.025,0.005,0,0

14,Arbitrary,DredgedChannel,1,0,0,0,0,0,0,0,1,0,0,0,0,0,0,0,0.81,0.18333333,0.00666667,0,0,0,0,0,0.97666667,0.02333333,0,0,0,0,0,0

15,Arbitrary,Heterogeneous,1,0,0,0,0,0,0,0,1,0,0,0,0,0,0,0,0.72,0.28,0,0,0,0,0,0,0.99,0.01,0,0,0,0,0,0

16,Arbitrary,MoundsCommon,1,0,0,0,0,0,0,0,0.9,0.1,0,0,0,0,0,0,0.45666667,0.3,0.09666667,0.06666667,0.05333333,0.02666667,0,0,0.74,0.23666667,0.02,0.00333333,0,0,0,0

17,Arbitrary,NEhighfreqrough,1,0,0,0,0,0,0,0,1,0,0,0,0,0,0,0,0.29,0.34,0.31,0.06,0,0,0,0,0.51,0.44,0.05,0,0,0,0,0

18,Arbitrary,ReefBorderedSediment,1,0,0,0,0,0,0,0,0.87,0.09,0.04,0,0,0,0,0,0.89,0.06,0.02,0.01,0.02,0,0,0,0.83,0.14,0.03,0,0,0,0,0

19,Arbitrary,ReefEdgeW,0.89,0.11,0,0,0,0,0,0,0.06,0.64,0.3,0,0,0,0,0,0.14,0.29,0.17,0.18,0.14,0.05,0.02,0.01,0.24,0.47,0.22,0.07,0,0,0,0

20,Arbitrary,ReefRidgeSE,0.9875,0,0,0,0,0,0,0,0.4275,0.4025,0.135,0.0225,0,0,0,0,0.18,0.3125,0.225,0.145,0.0775,0.0325,0.01,0.005,0.545,0.3825,0.0475,0.0125,0,0,0,0

21,Arbitrary,SmoothSedimented,0.5,0.5,0,0,0,0,0,0,1,0,0,0,0,0,0,0,1,0,0,0,0,0,0,0,1,0,0,0,0,0,0,0

22,Arbitrary,SpurGrooveLike,0,1,0,0,0,0,0,0,0.25,0.7,0.05,0,0,0,0,0,0.35,0.46,0.12,0.07,0,0,0,0,0.43,0.51,0.06,0,0,0,0,0

23,VideoGroundTruth,CaCO3

Boulders,1,0,0,0,0,0,0,0,0.218,0.424,0.322,0.036,0,0,0,0,0.348,0.326,0.172,0.084,0.044,0.012,0.014,0,0.34,0.53,0.13,0,0,0,0,0

24,VideoGroundTruth,CaCO3

Rock,0.97556962,0.02443038,0,0,0,0,0,0,0.56743544,0.25593544,0.10371772,0.04291139,0.02417722,0.0058227

8,0,0,0.35642405,0.29005949,0.17215063,0.09199241,0.05778101,0.02093291,0.0063557,0.0043038,0.62682405,

0.25896582,0.07770127,0.02978734,0.00583671,0.00088608,0,0

25,VideoGroundTruth,CaCO3 Rock and

Sand,1,0,0,0,0,0,0,0,0.8465,0.1135,0.0365,0.0035,0,0,0,0,0.4885,0.2855,0.123,0.0575,0.03,0.012,0.003,0.0005,0.78

5,0.1875,0.027,0.0005,0,0,0,0

26,VideoGroundTruth,CaCO3

Rubble,1,0,0,0,0,0,0,0,0.53277705,0.32574754,0.12,0.01918033,0.00229508,0,0,0,0.37199344,0.31421967,0.1762

3443,0.07131639,0.03885738,0.01393443,0.01065574,0.00278689,0.62342295,0.3269,0.04459508,0.00393443,0.0

0114754,0,0,0

27,VideoGroundTruth,CaCO3 Rubble and

Sand,1,0,0,0,0,0,0,0,0.49833333,0.32,0.13333333,0.04833333,0,0,0,0,0.15333333,0.27833333,0.26833333,0.15166

667,0.085,0.045,0.015,0.00333333,0.54,0.37333333,0.08,0.00666667,0,0,0,0

28,VideoGroundTruth,Sand,0.95775281,0.04224719,0,0,0,0,0,0,0.75772921,0.14046629,0.07149438,0.02362472,0

.00595506,0.00073034,0,0,0.53319438,0.24216404,0.11381798,0.05713933,0.03466011,0.01218989,0.00488427,0

.00194888,0.75461517,0.18720674,0.04546966,0.00940337,0.00302472,0.0002809,0,0

29,VideoGroundTruth,Sand and CaCO3

Rock,1,0,0,0,0,0,0,0,0.83913043,0.11826087,0.04043478,0.00217391,0,0,0,0,0.34956522,0.35565217,0.17,0.0656

5217,0.03565217,0.0173913,0.00521739,0.00086957,0.67521739,0.29217391,0.03,0.00217391,0.00043478,0,0,0