The Use of Sidescan Sonar and Acoustic Classification for Benthic Habitat Mapping; an Alternative Methodology for Environmental Monitoring

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Outline

- Concept
- Acoustic Bottom Classification (ABC) Methodology
- Project Examples
- Potential Uses in Coastal Restoration Monitoring

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Concept
Seabed Classification Methods

- Visual Classification Methods (divers, video, photography)
- Mechanical Classification Methods (divers, grab samples, cores, probes)
- Acoustic Classification Methods (singlebeam, multibeam, sidescan sonar)

Concept

Visual Classification

"Pros"

- Allows for more human based interaction.
- Allows for detailed, qualitative analysis.

"Cons"

- Human interaction can create biases.
- Labor and time intensive.
- Field work can only be completed during optimum weather and water clarity windows.
- Large survey areas are classified using localized, representative transects.
- Can be expensive.

Concept
Mechanical Classification

"Pros"

- Allows for more human based interaction
- Allows for more detailed surficial data collection.
- Allows for collection of physical samples for additional, later evaluation.

"Cons"

- Human interaction can create biases.
- Labor and time intensive.
- Field work can only be completed during optimum weather and water clarity windows.
- Large survey areas are classified using localized, representative transects.
- Can be expensive.
- May damage collected material.

Concept
Acoustic Classification

"Pros"

- Can cover large areas quickly.
- The entire survey area is covered and analyzed using swath data.
- Can be less expensive and generally involves a smaller field crew.
- Human biases in data reduction are reduced or eliminated

"Cons"

- Data analysis can be time intensive depending on the size of the data set (however, this is completed in the background without significant human interaction).
- Some groundtruthing is required to ensure proper class identification

Concept

Acoustic Classification Purpose

- To automate classification of sidescan sonar data in order to save time/money and improve objectivity in data reduction.
- To enable repeatable, accurate and objective pattern recognition over large survey areas using multiple sidescan surveys.
- To allow for non-biased habitat change recognition over multiple surveys.
- To allow the detection of features indiscernible to the the human eye.

Concept

Acoustic Classification Applications

- Pipeline Identification and Mapping
- Artificial Reef As-Built Mapping
- Nearshore Hardbottom Mapping
- Change Analysis Over Time
- Shellfish Bed Mapping
- Seagrass Mapping

Concept
Geophysical Methods

- Singlebeam Sonar
- Multibeam Sonar
- Sidescan Sonar

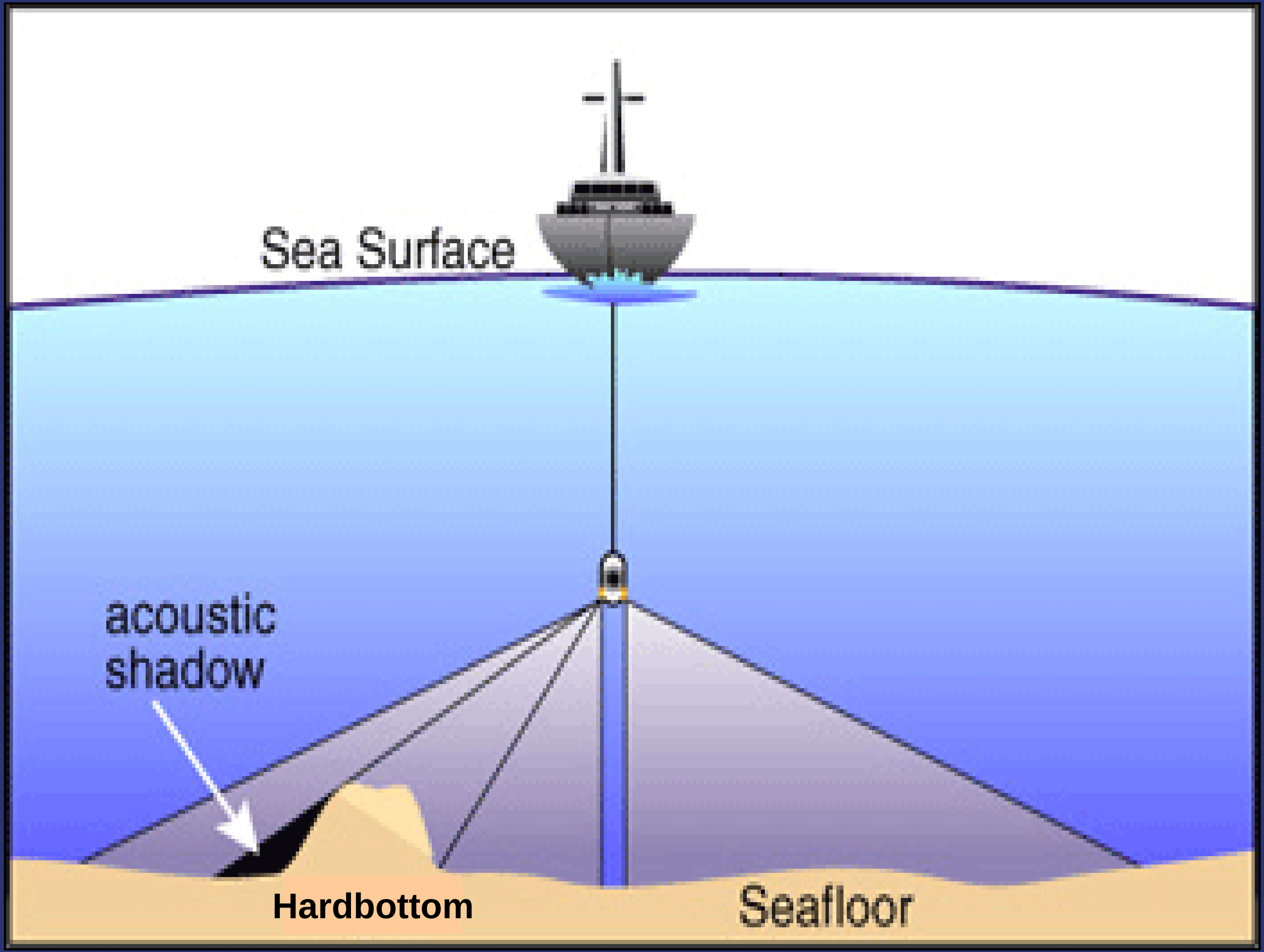
Concept

Sidescan Sonar

- Tool used for mapping the sonar backscatter of the seabed for a wide variety of purposes.

- Sidescan use a sonar device that emit conical or fan-shaped pulses down toward the seafloor across a wide angle perpendicular to the path of the sensor through the water.

Concept
Sidescan Sonar



Concept

Sidescan Sonar

- Sidescan sonars are available in a wide range of frequencies.
- Dual-frequency sidescan sonars allow for more detailed analysis.
- Lower frequencies tend to penetrate the seafloor more than higher frequencies which can allow for the detection of surficial features such as pipelines by QTC.

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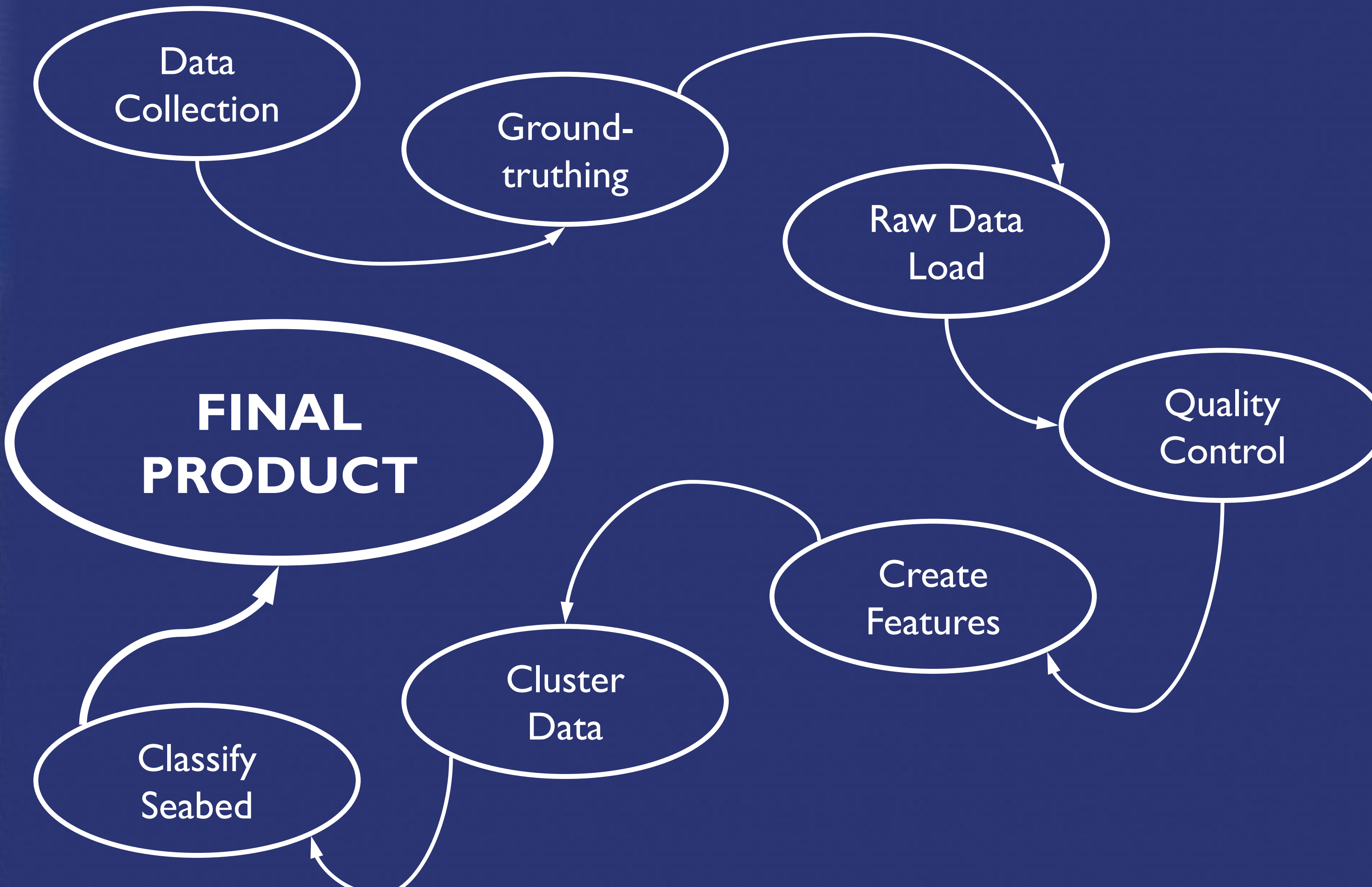
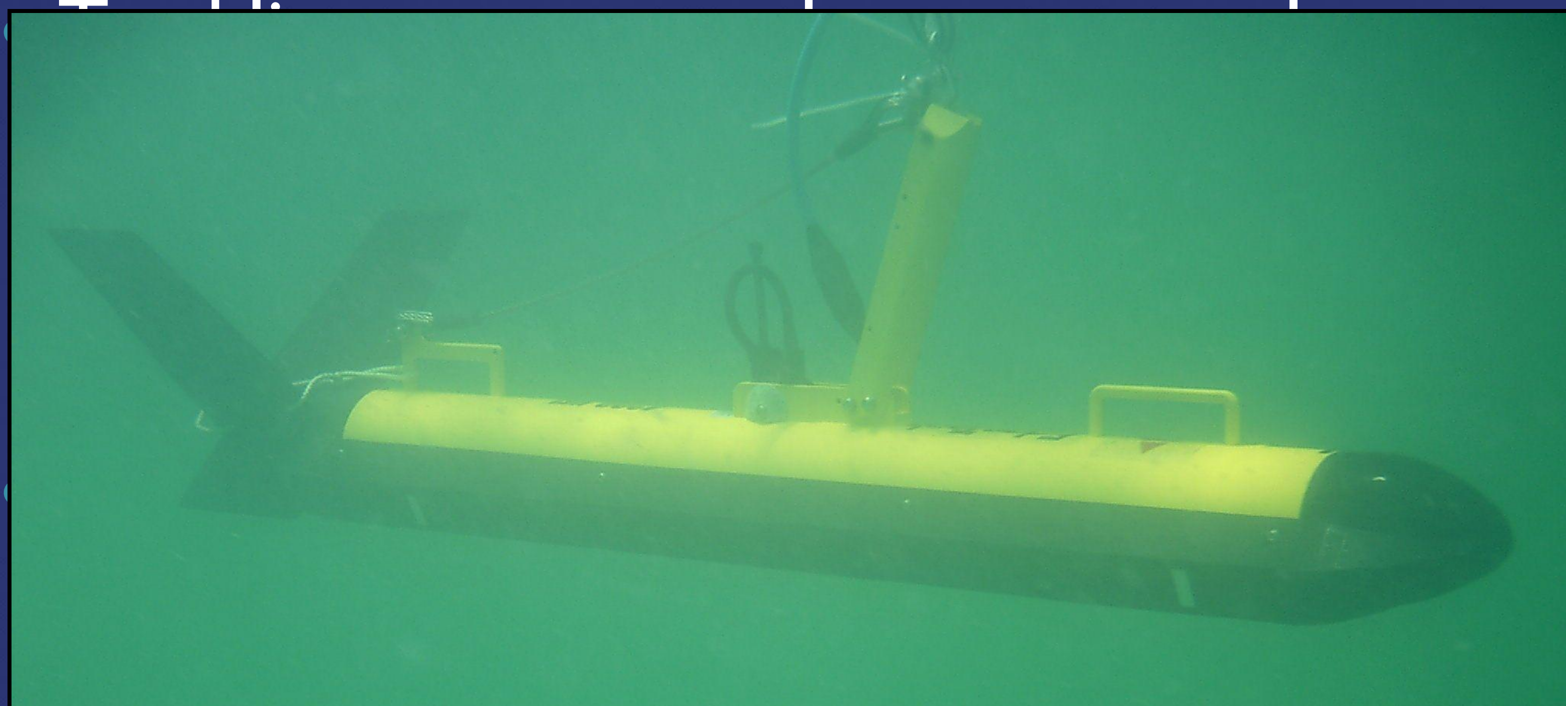
ABC Methodology

Process Outline



ABC Methodology
Data Collection

- Data is collected using an Edgetech 4200-HFL (300/600 khz) sidescan sonar.

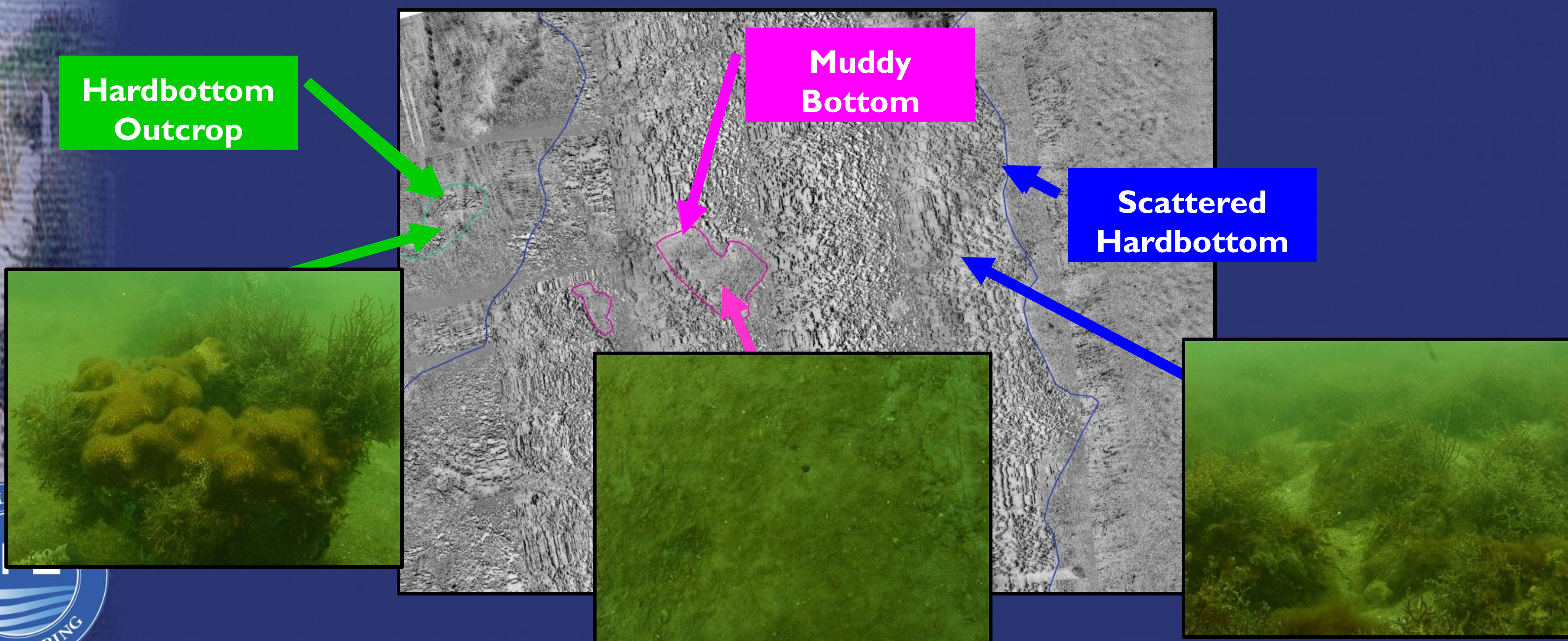


reduction.

ABC Methodology

Groundtruthing

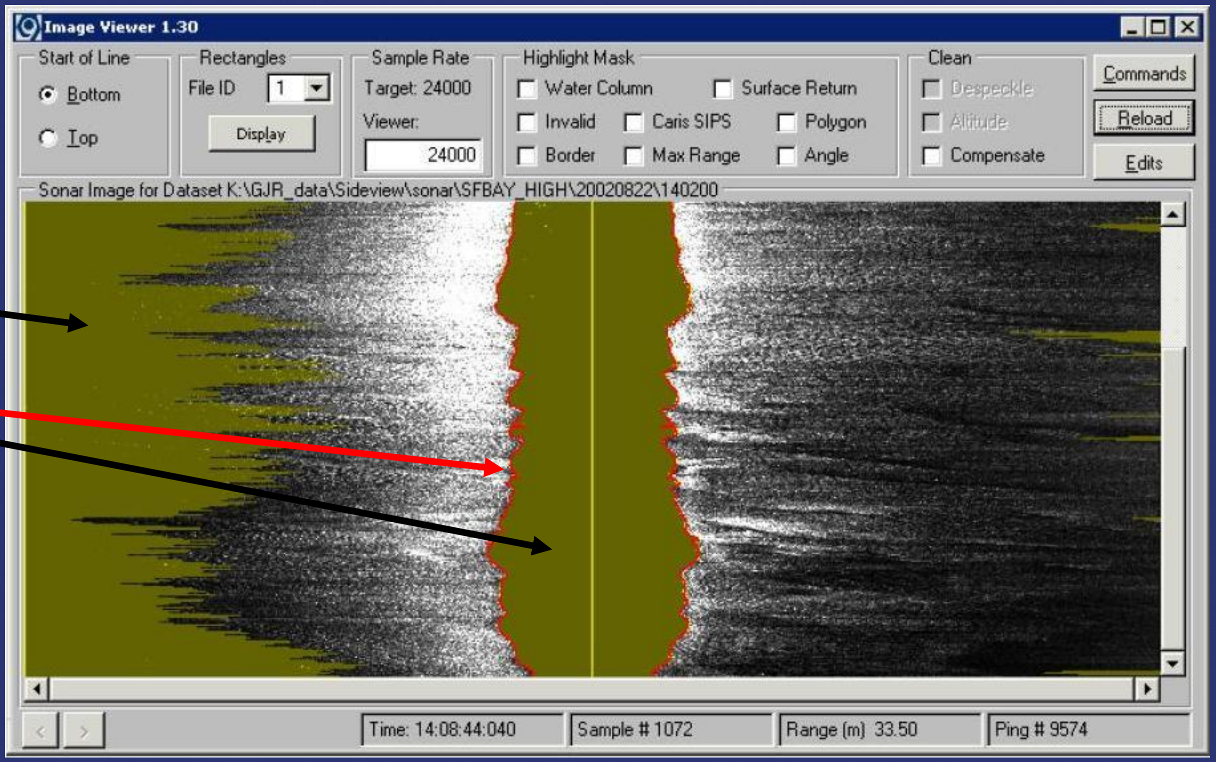
- Data is visually inspected by the sidescan operator and noticeable differences are targeted for diver investigation.



ABC Methodology

Quality Control

- Images are then bottom tracked and compensated, or “cleaned” of any poor data to ensure the best final classification possible.



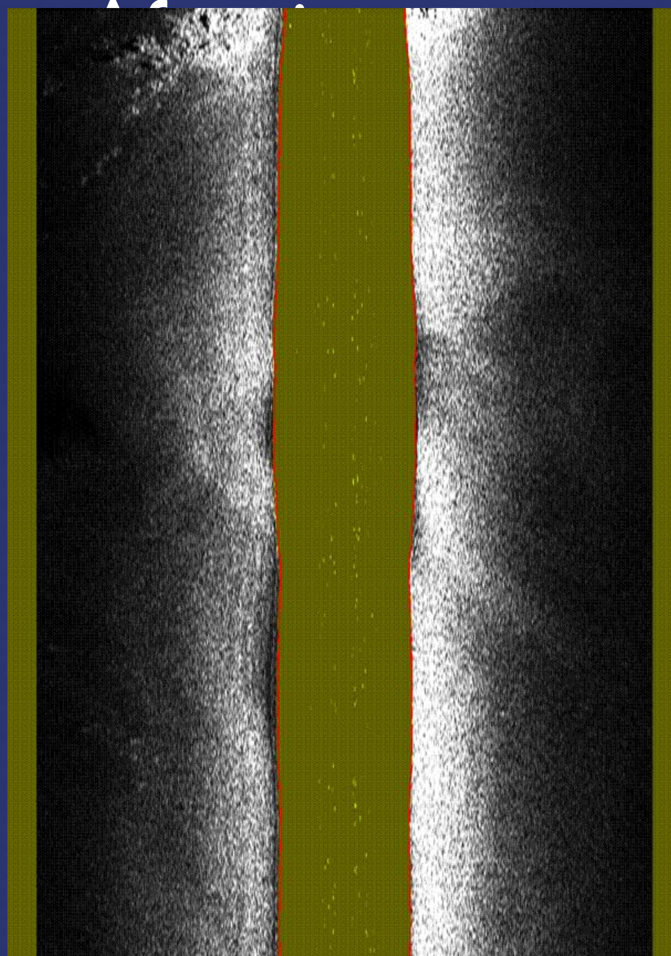
Water Column and Shoreline Compensated

Bottom Tracked Data

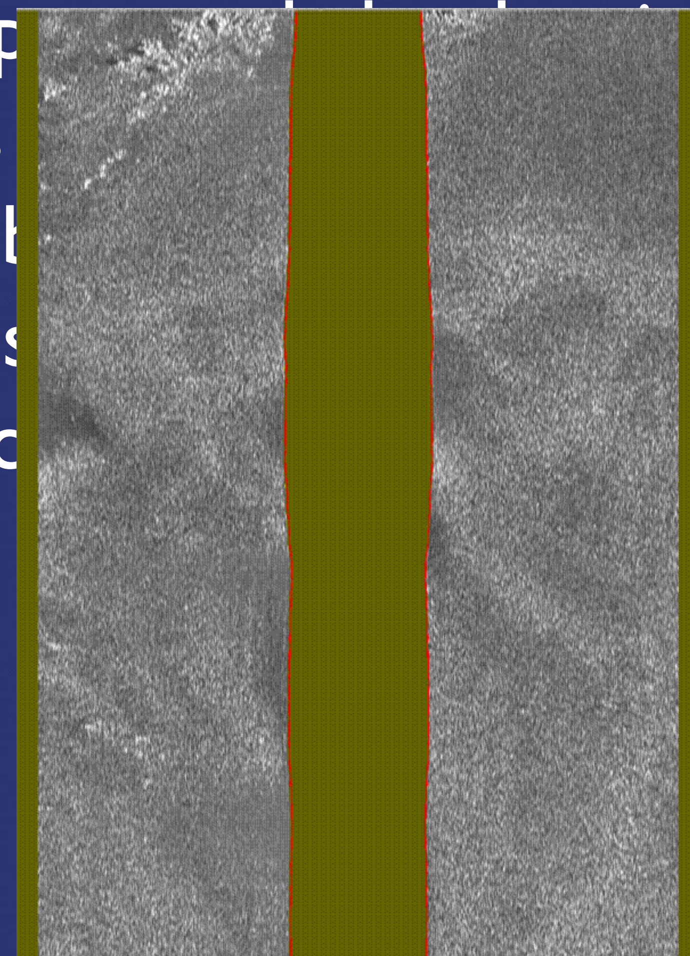
ABC Methodology

Quality Control

BEFORE



AFTER



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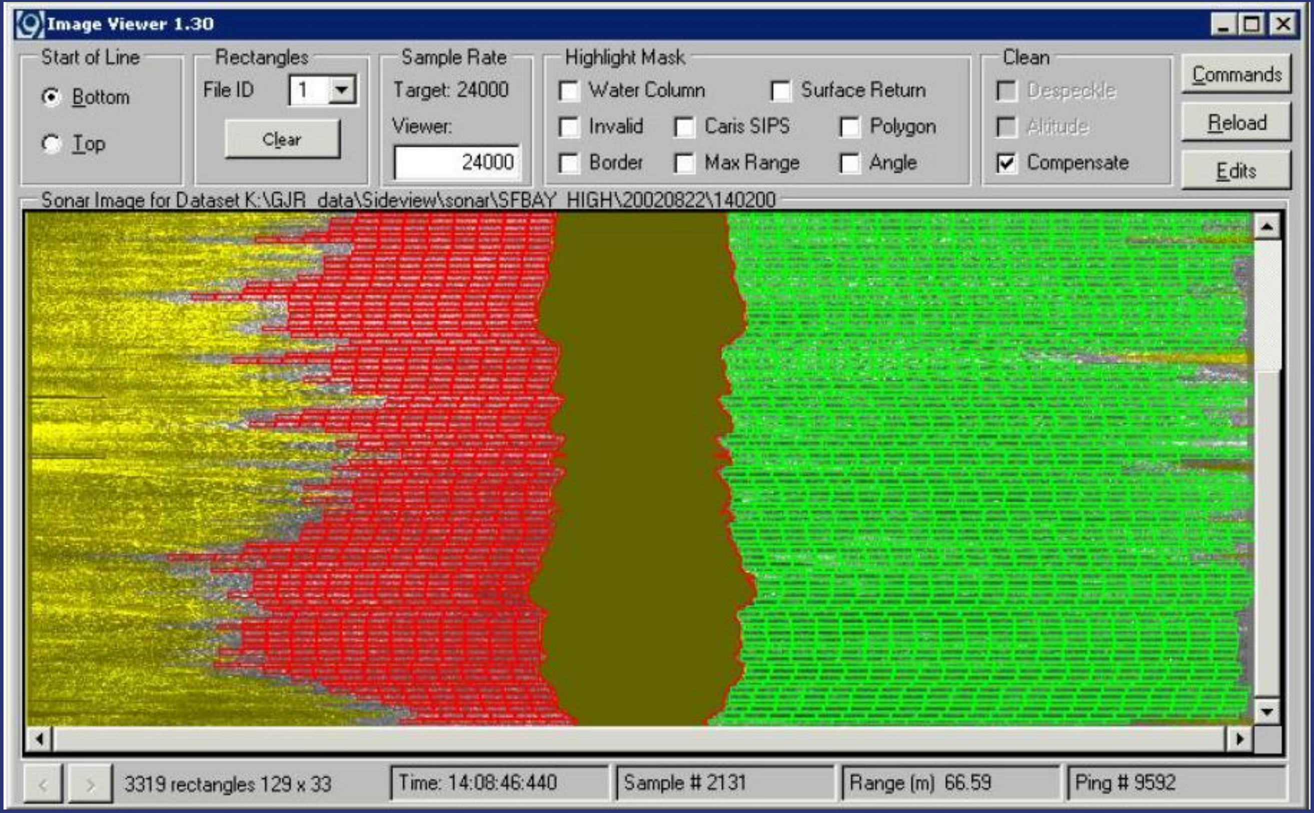
ABC Methodology

Create Features

- After images have been cleaned, the data that has been determined to be acceptable is gridded into rectangles to generate features.



ABC Methodology
Create Features: "FFV"

- For each rectangle of an image, a set of over 100 individual statistical features are calculated by a suite of algorithms. The resulting information is called a ***Full Feature Vectors***, or "FFV"
- FFV's are created for each image in the data set and then merged into one large file thus incorporating all of the data throughout the entire survey area.

ABC Methodology

Create Features: Algorithms

- **Basic Statistics:** Mean, standard deviation, and higher-order moments are indicative of acoustic impedance changes and interface roughness
- **Quantile and Histogram:** These measure the distribution of backscattered information intensities at low resolution
- **Fast Fourier Transforms (FFTs):** FFTs are used to find power spectra, which describe statistical characteristics on many resolution scales
- **Ratios based on Power Spectra (Pace):** Ratios of log-normalized power in various frequency bands provide good discrimination for classifying images.
- **Gray-Level Co-occurrence Matrices (GLCMs):** GLCMs describe the amplitude changes over selected distances and directions in the image patch, and are widely used to assess texture.
- **Fractal Dimension:** Fractal dimension is a sensitive measure of the distribution and structure of both backscatter and depth variations.

ABC Methodology
Multivariate Statistical Analysis

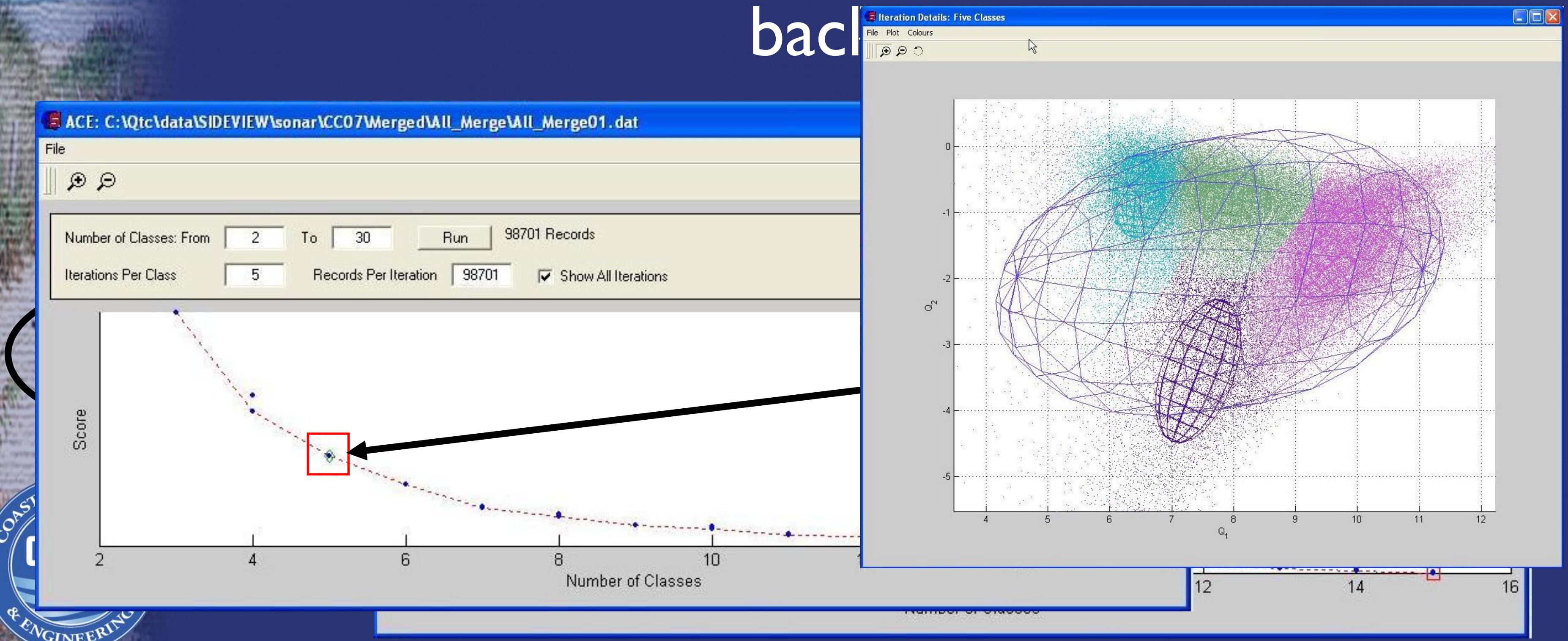
- The dimensions of the FFVs are reduced by multivariate statistical processing to isolate the combinations of features that are responsible for most of the diversity in the data set.
- This is a proprietary Quester Tangent analysis routine that, through Principal Components Analysis, selects the three features that are most useful for the discrimination task at hand based upon the feature being analyzed.
- Results in three "Q" values

ABC Methodology

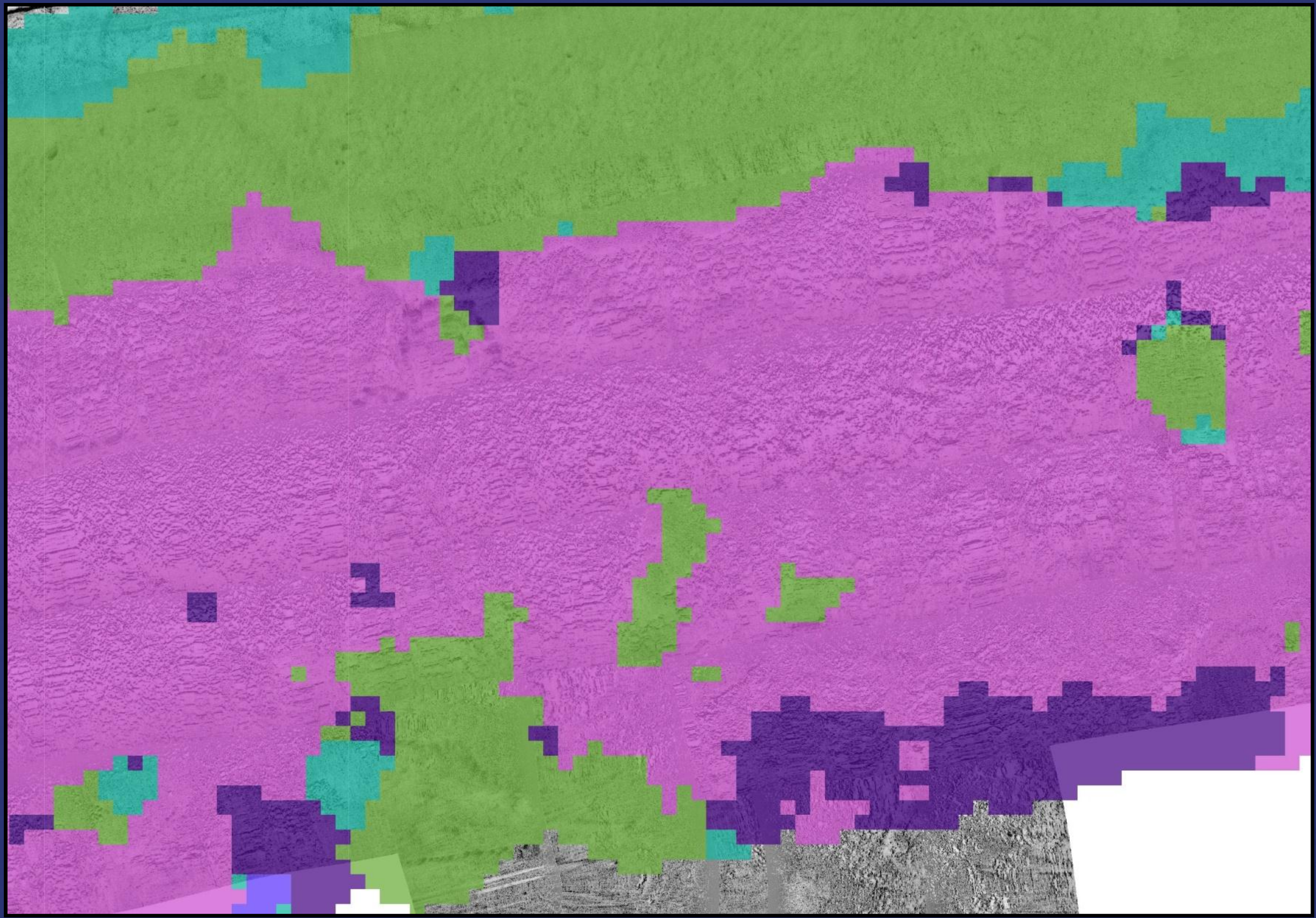
Data Clustering

After all of the features have been generated the data is clustered to group similar data into classes according to bacl

A legitimate number of classes are picked based upon the clustering results and then analyzed.



ABC Methodology
Final Product



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Project Examples
Pipeline Identification

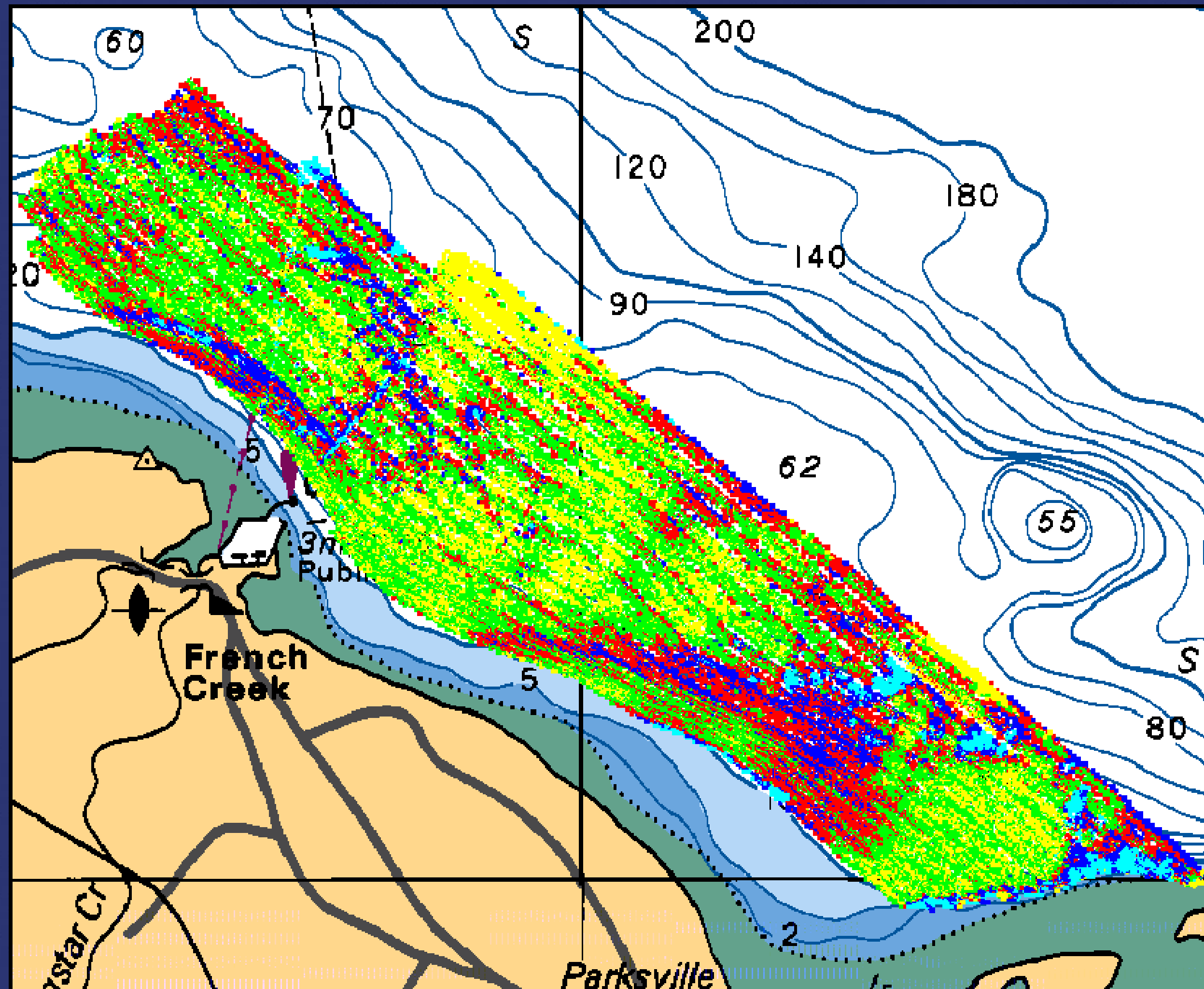
- Survey conducted off of Vancouver Island by Quester Tangent Corporation.
- Five statistically significant classes were identified.
- A pipeline was located in the area that ran from the shore into the bay.

Vancouver Island
Canada

Project Examples

Pipeline Identification

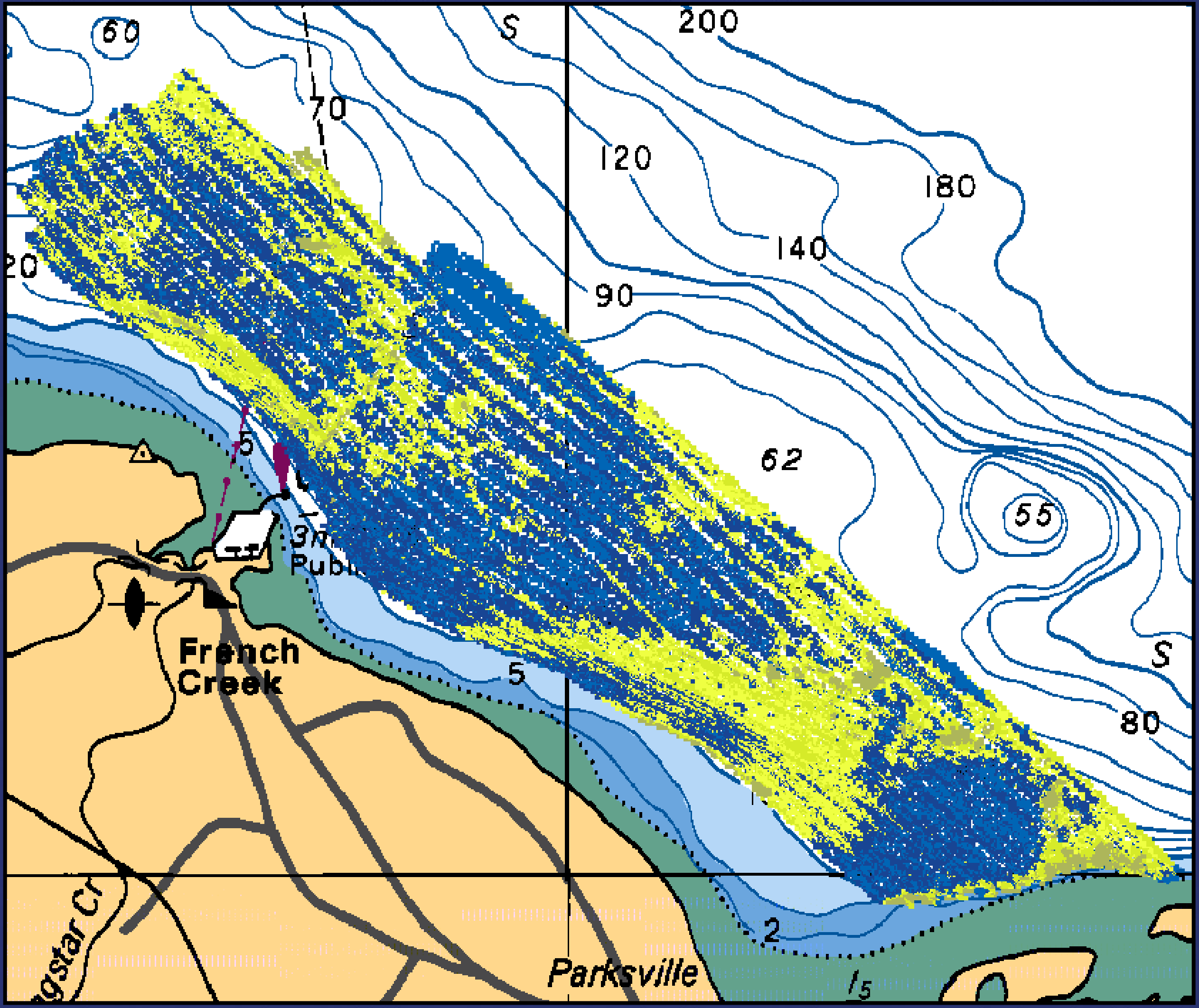
Five classes displayed as ***discrete*** colors



Vancouver Island
Canada

Project Examples
Pipeline Identification

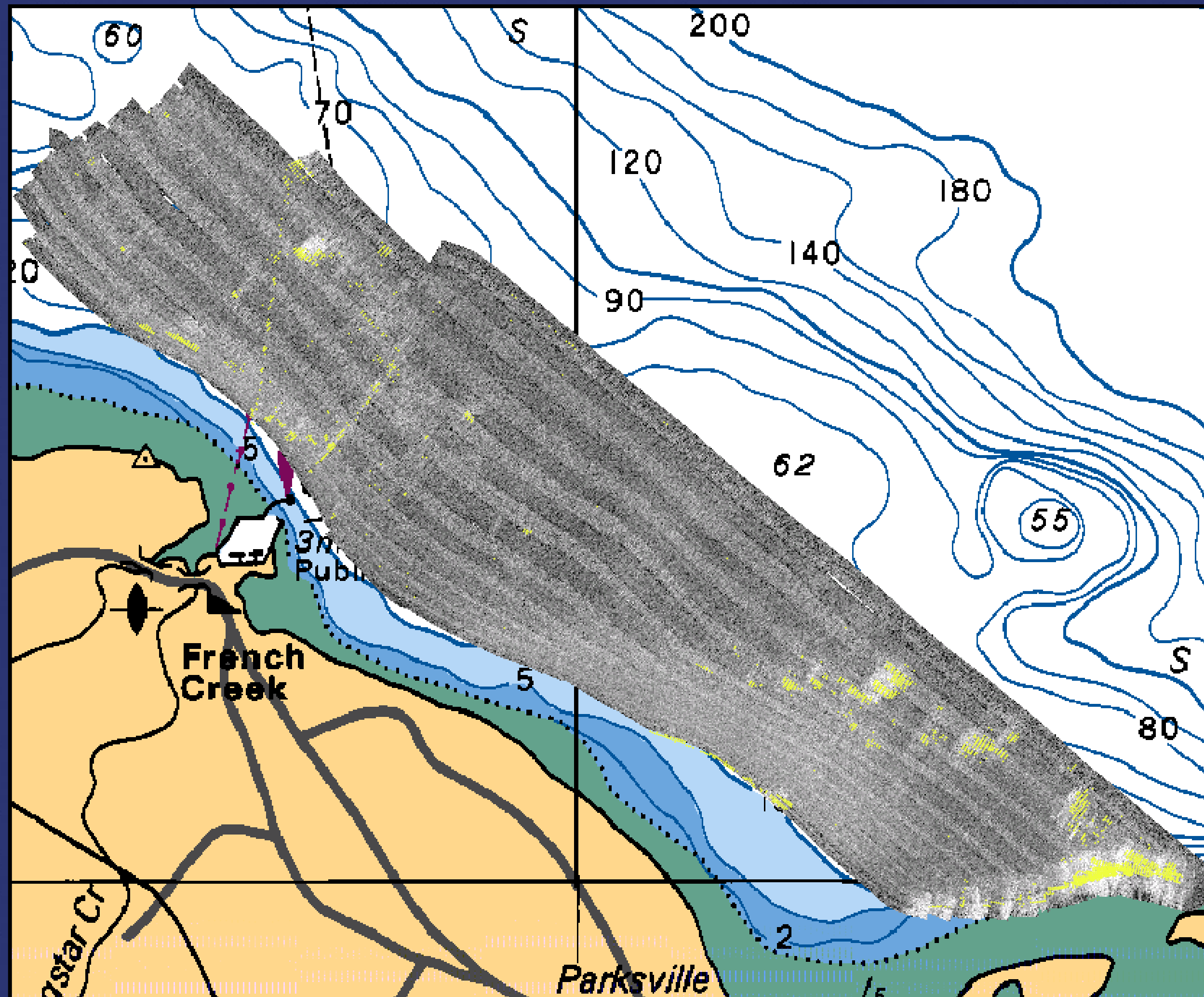
Five classes displayed as ***similar*** colors



Vancouver Island
Canada

Project Examples
Pipeline Identification

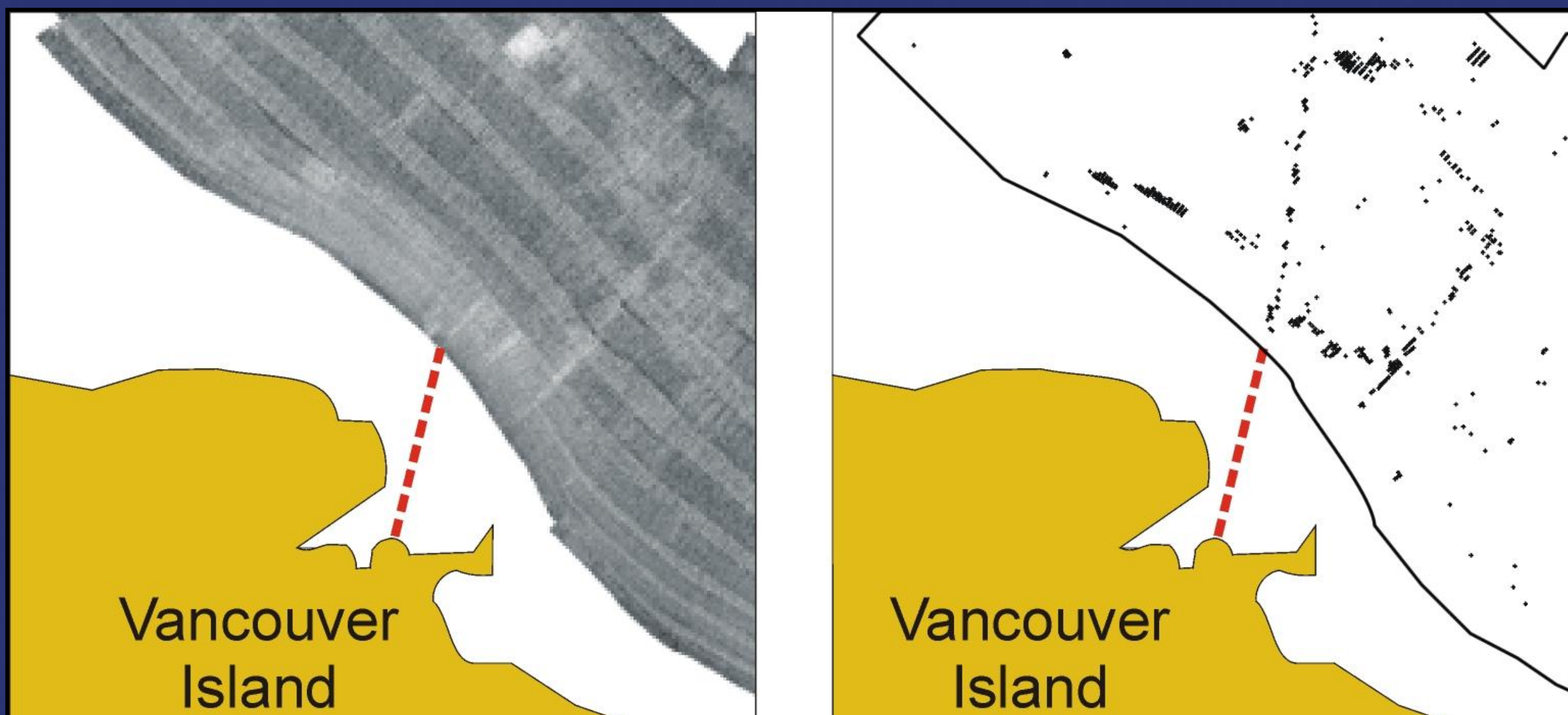
With only class #5 displayed, the pipeline becomes visible



Vancouver Island
Canada

Project Examples
Pipeline Identification

Backscatter Mosaic Class #5 Only



Project Examples
Artificial Reef Mapping

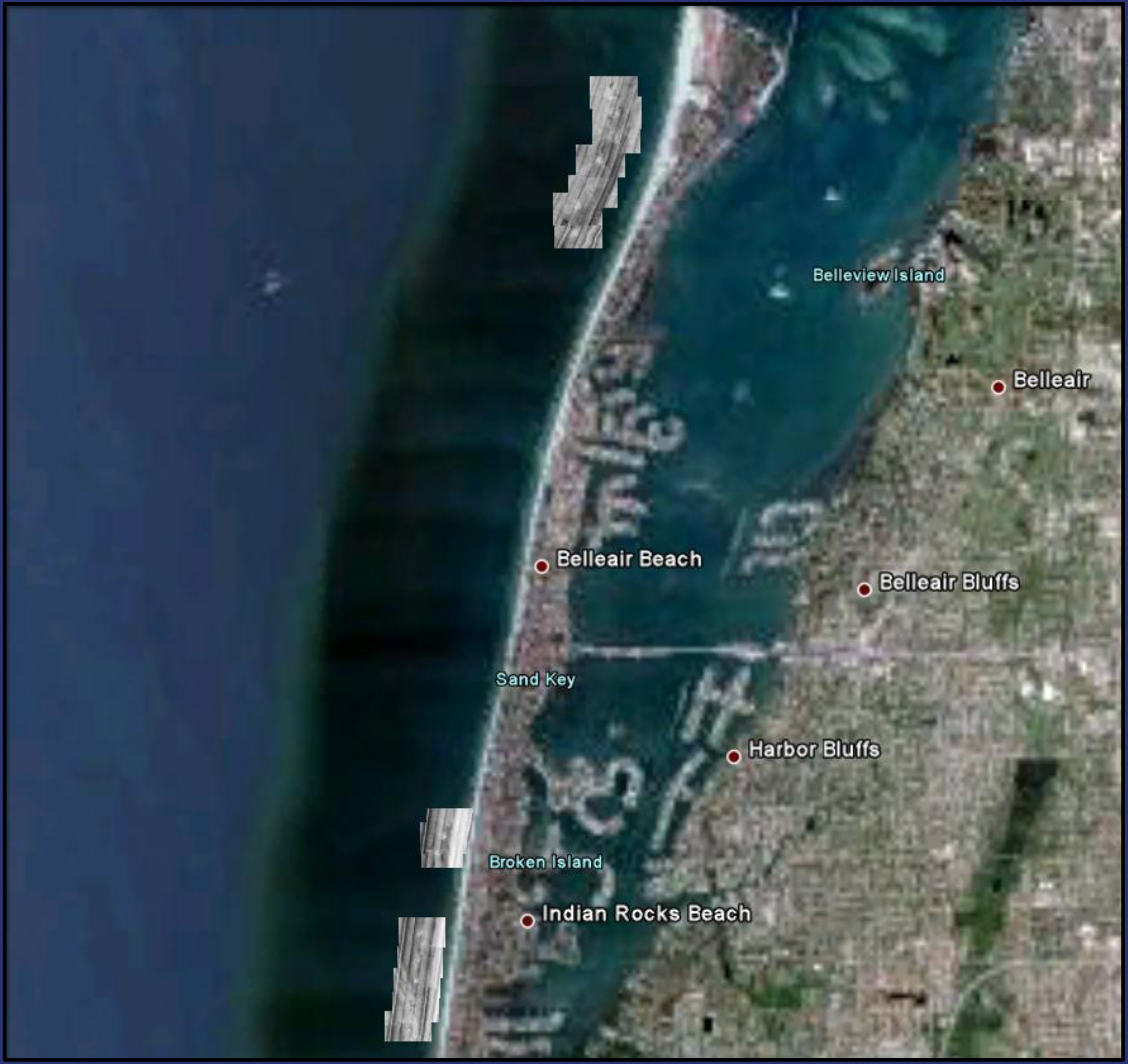
- Survey conducted off of Sand Key, FL in Pinellas County by CPE.

- Purpose was to map the extents of the artificial reefs and the nearshore harbottom edge.

Sand Key, Pinellas County

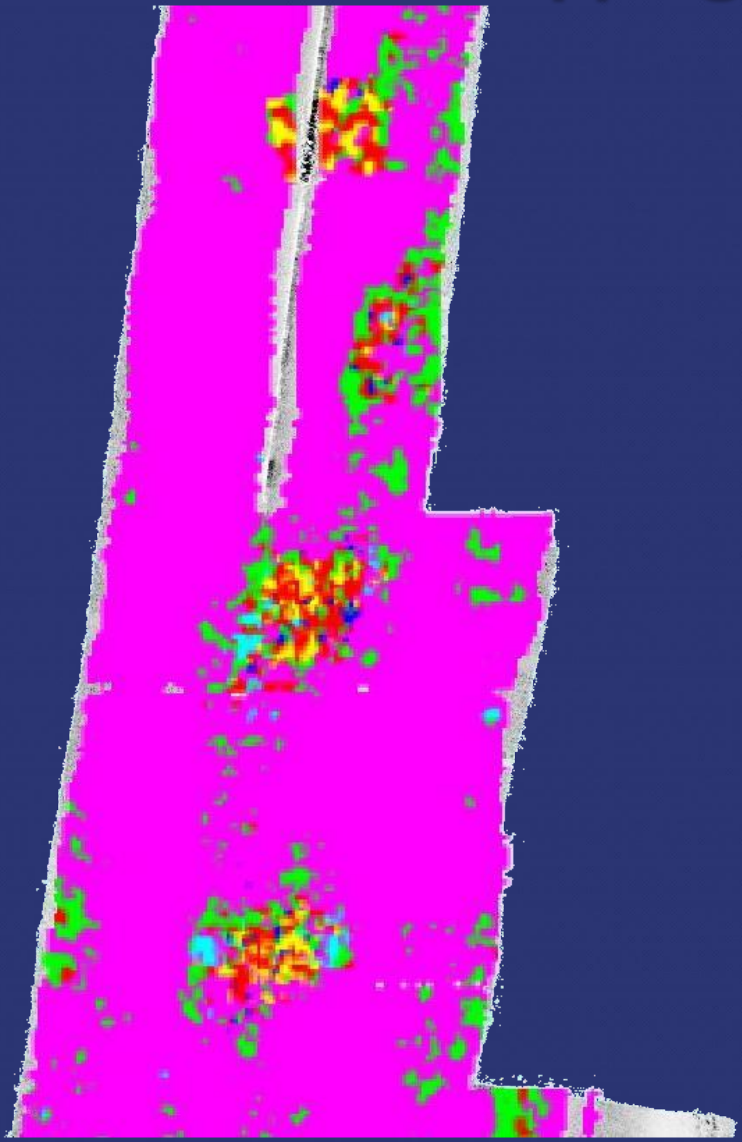
Project Examples

Artificial Reef Mapping



Sand Key,
Pinellas County

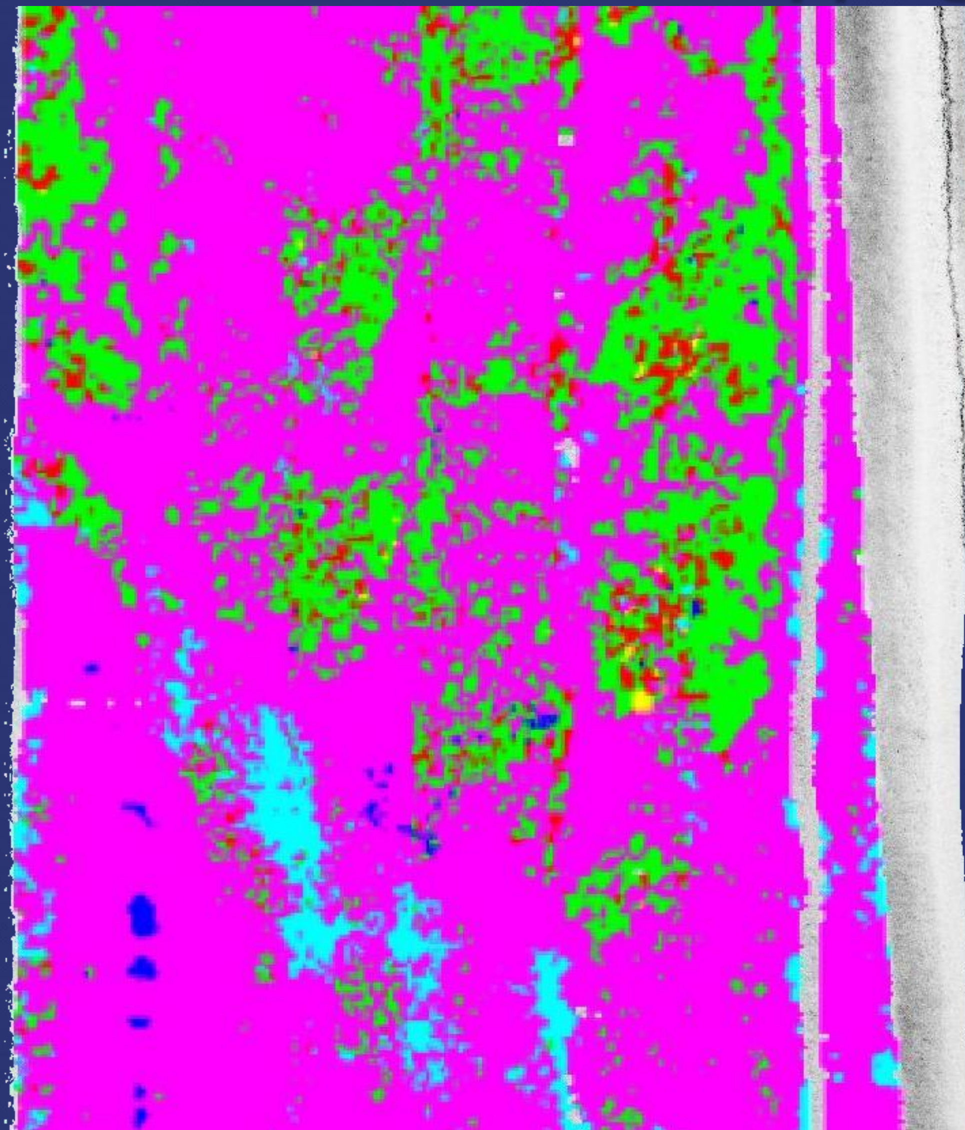
Project Examples
Artificial Reef Mapping



Sand Key,
Pinellas County

Project Examples

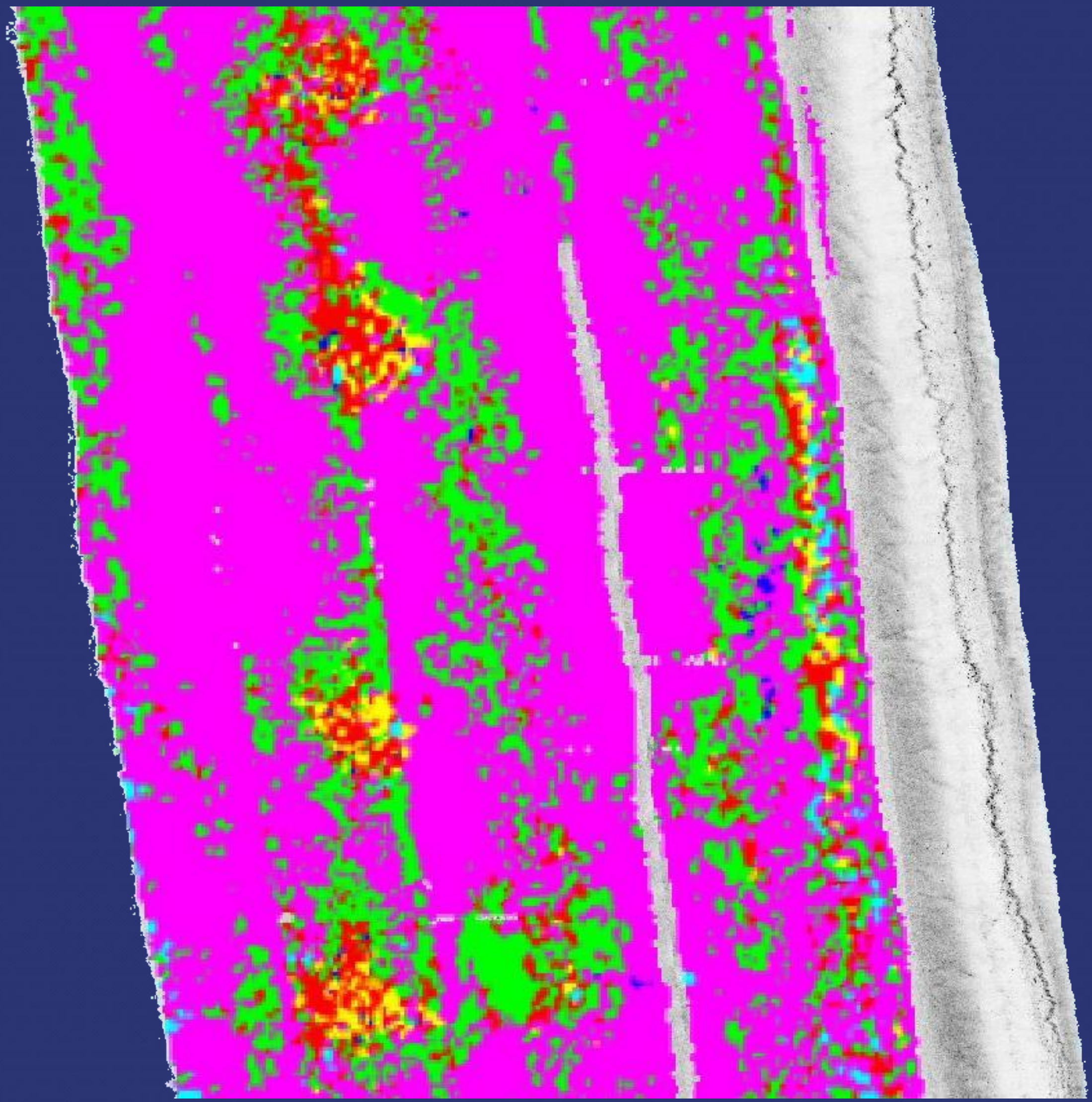
Artificial Reef Mapping



Sand Key,
Pinellas County

Project Examples

Artificial Reef Mapping

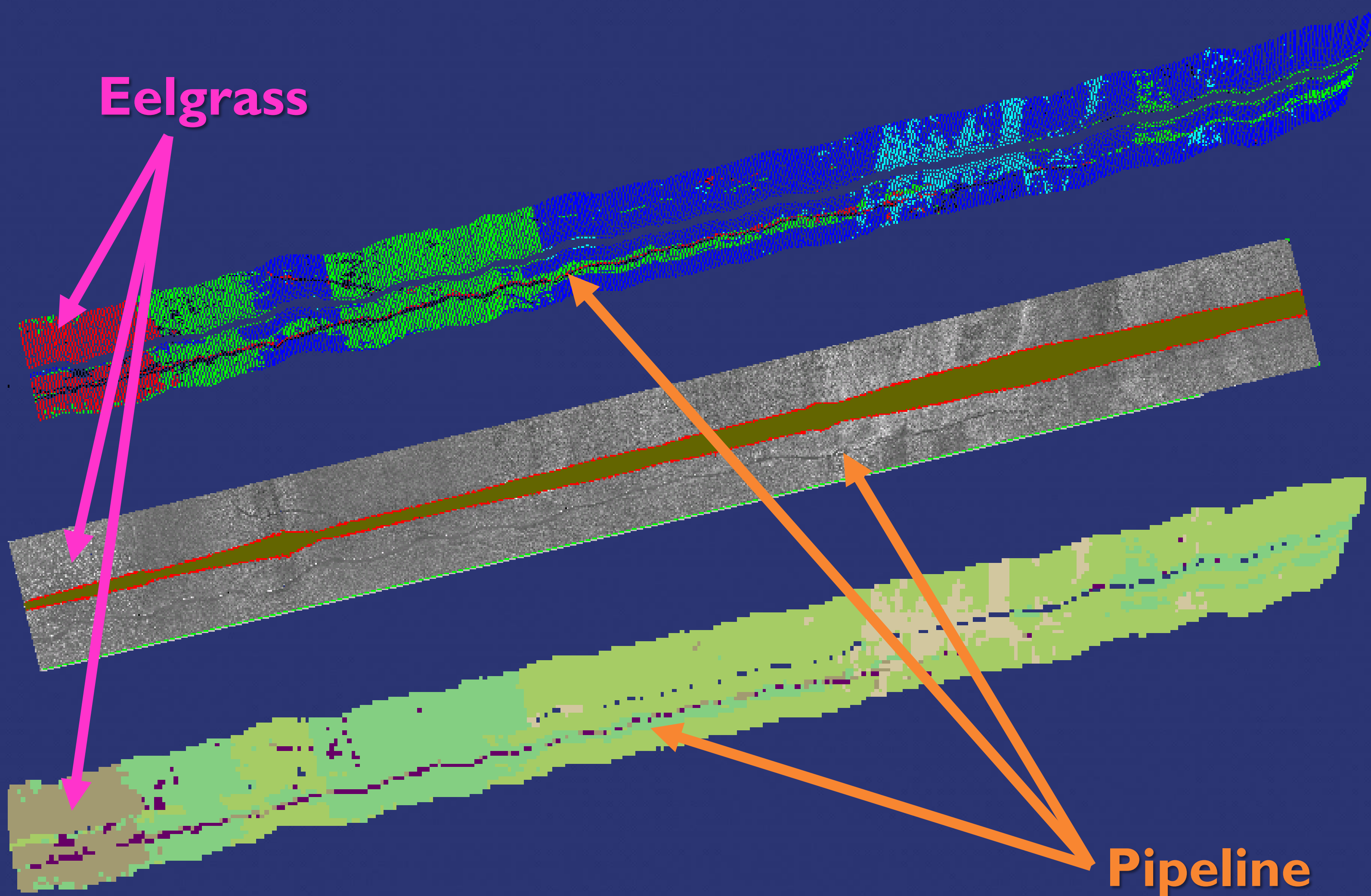


Project Examples
Seagrass Mapping

- Bazan Bay, Sidney, BC. Bottom classification shows the presence of eelgrass within a sandy bottom marine environment.
- Ses Salines Natural Park Ibiza, Spain. Interpolated classification is overlaid on vertically exaggerated bathymetry. Bottom classification successfully identified distinct regions covered by *Posidonia* and *Cymodocea* seagrass in addition to changes in sediment type.

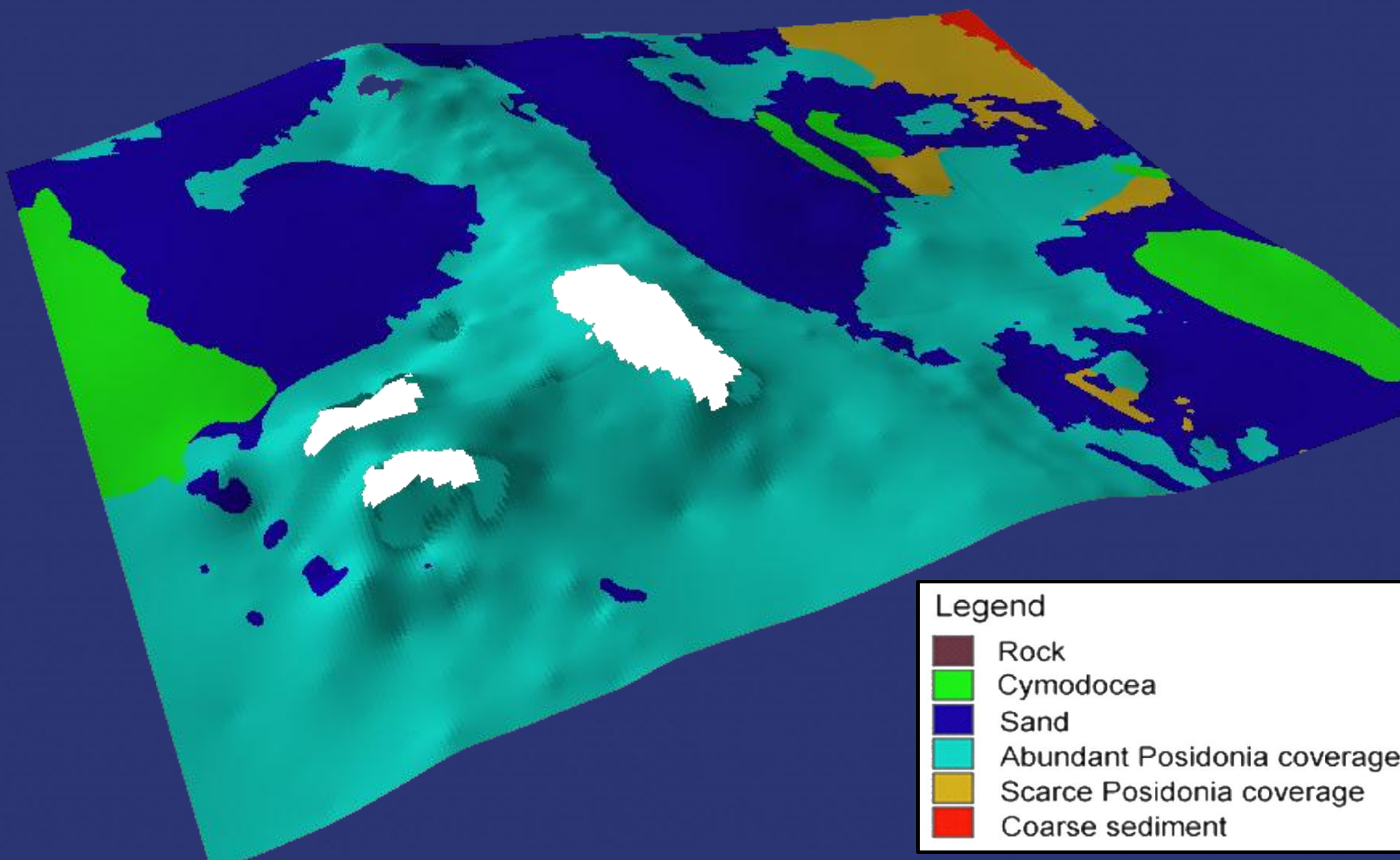
Bazan Bay
Vancouver, Canada

Project Examples
Seagrass Mapping



Ses Salines Natural Park
Ibiza, Spain

Project Examples
Seagrass Mapping



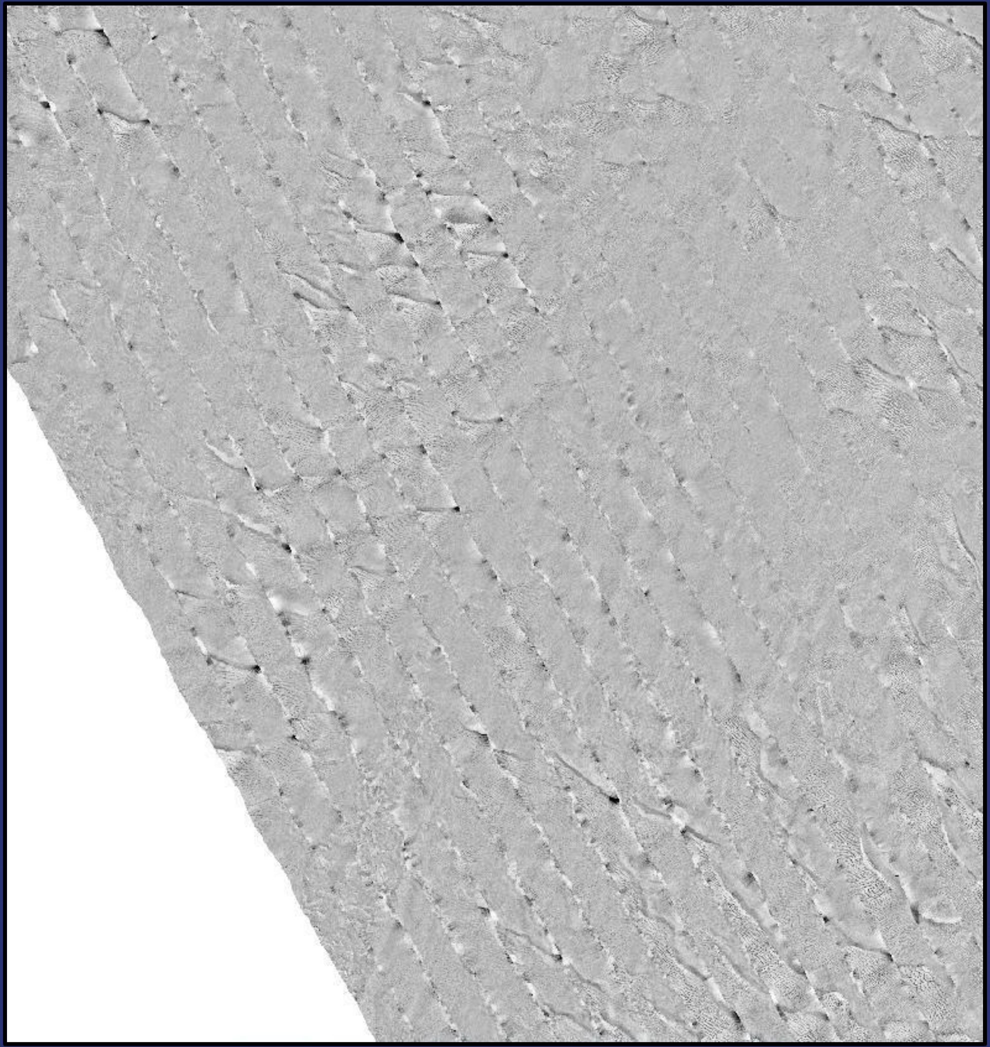
Courtesy of Ecohydros

Project Examples
Borrow Area Mapping

- Survey conducted off of the coast of Massachusetts by CPE.
- Purpose was to map the extents of a proposed borrow site for potential environmental and cultural resource impacts.

Project Examples
Borrow Area Mapping

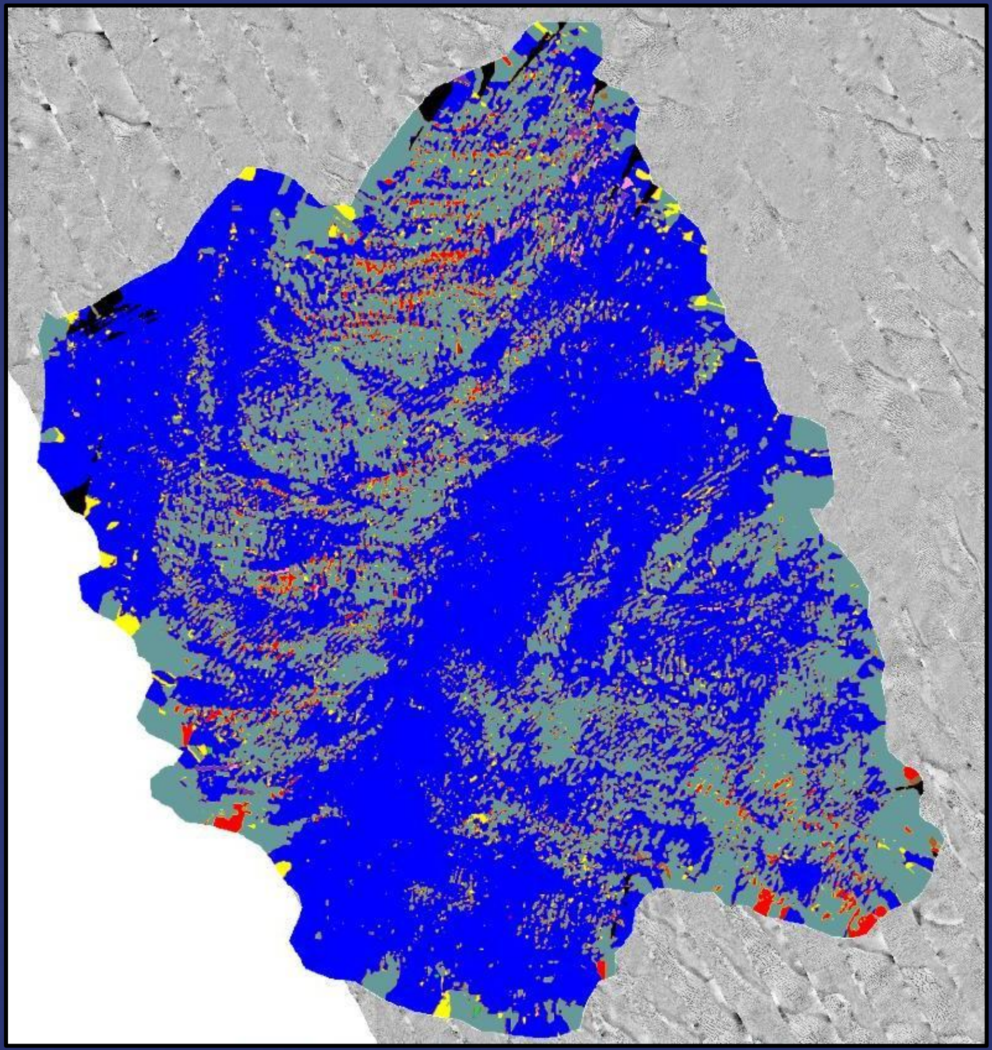
Sidescan
Sonar
Mosaic



Project Examples

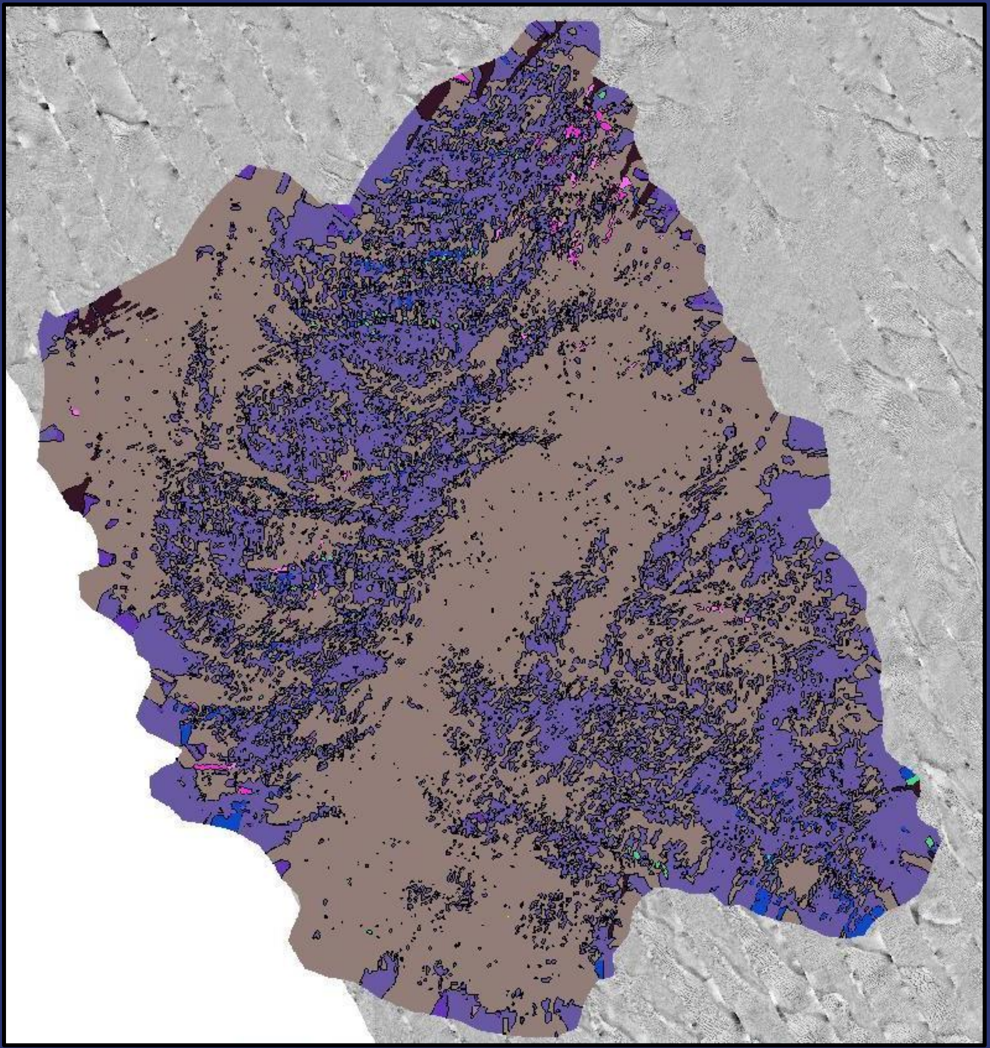
Borrow Area Mapping

Five Discrete Classes



Project Examples
Borrow Area Mapping

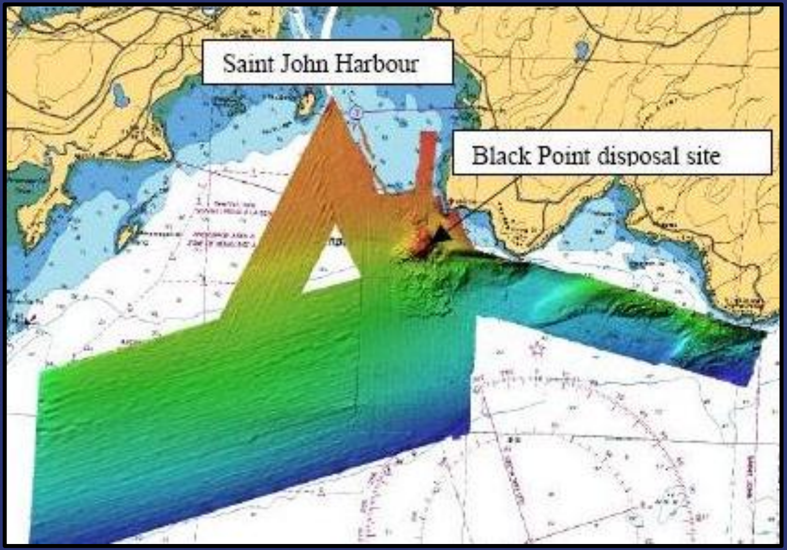
Five
Classes
Plotted
With
Similar
Colors



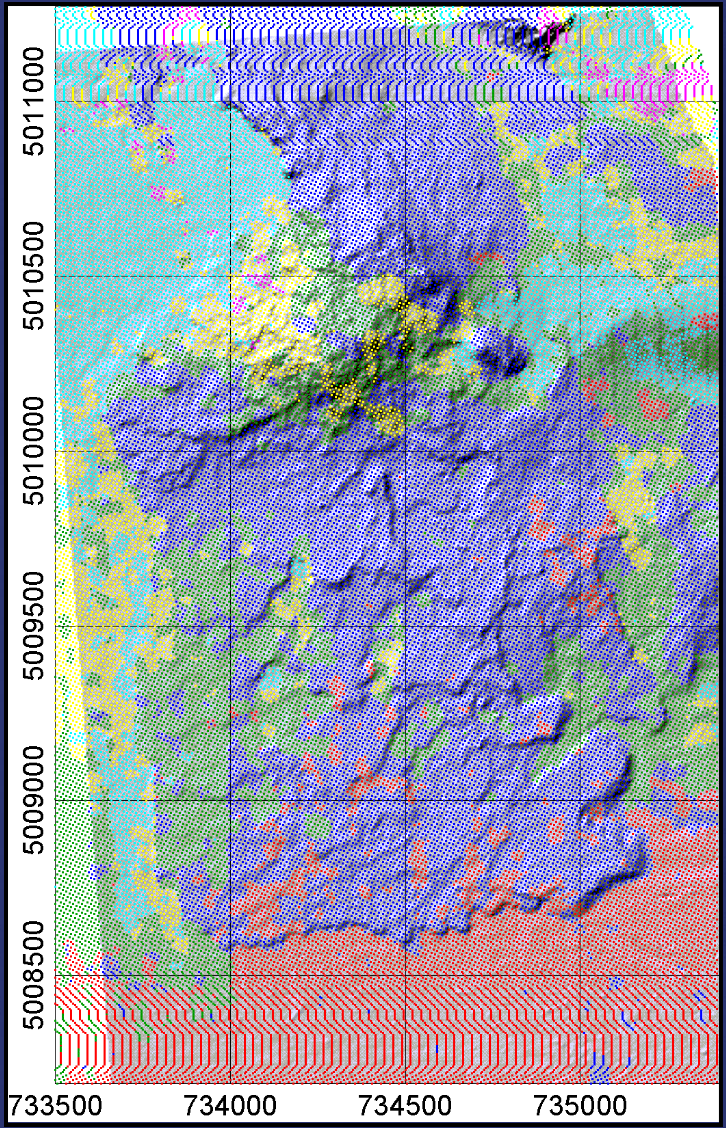
Project Examples
Mapping Changes Over Time

- Survey conducted off Saint John, New Brunswick on the East coast of Canada.
- Purpose was to map the change of a dredge spoil disposal site over time.

Project Examples
Mapping Changes Over Time



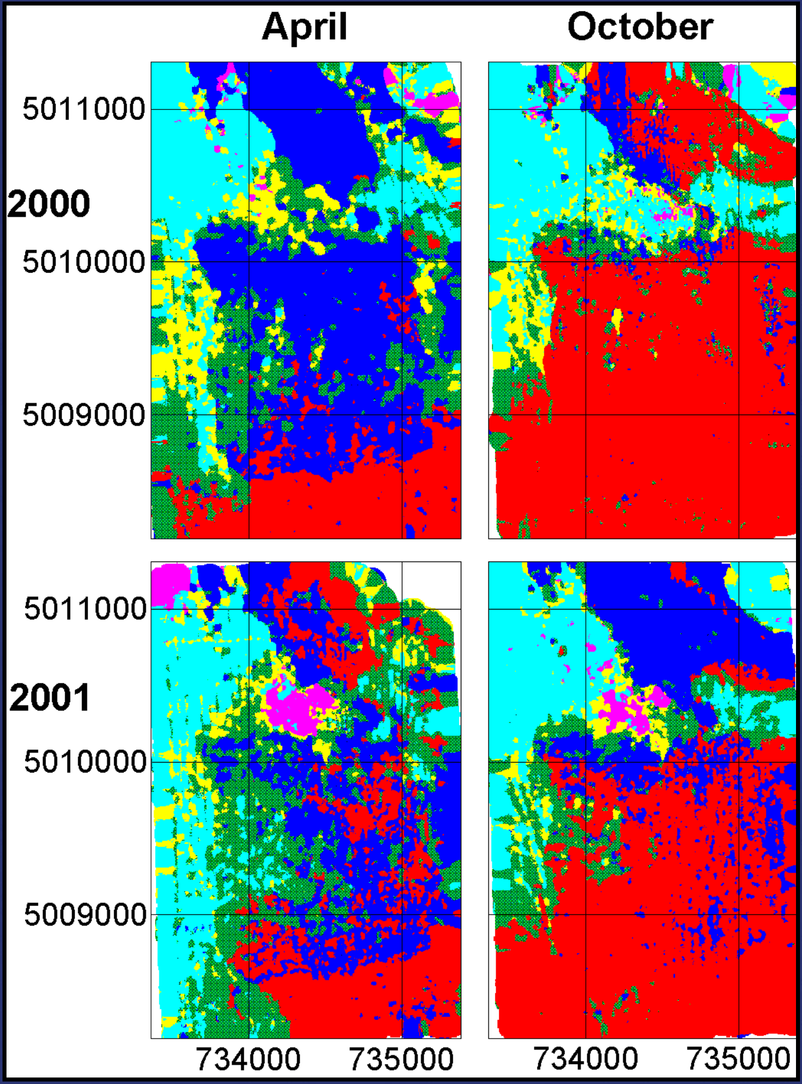
Project Examples
Mapping Changes Over Time



Project Examples
Mapping Changes Over Time

BOTTOM PHOTOGRAPHS IN AREAS OF THE SIX CLASSES

#	Colour	Description
1	Red	Silt, some pebbles
2	Green	Silt (low visibility)
3	Blue	Silt, some pebbles, few small rocks
4	Cyan	Silt, plentiful pebbles
5	Yellow	Silt (low visibility)
6	Magenta	No photographs in any Class 6 area



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Potential Uses
Coastal Monitoring

Habitat Mapping

Direct Impacts

Indirect Impacts

For Both Project and Borrow Areas

Potential Uses
Coastal Monitoring

Habitat Mapping

- Provide baseline mapping of seabed type within an entire survey area based on swath geophysics.
- Can map habitats of interest, including hardbottom, seagrass, benthic organisms, etc.
- Can help determine avoidance buffers for resource protection
- Minimally weather dependent.
- Not dependent on visibility restrictions.

Potential Uses
Coastal Monitoring

Direct Impacts

- Post-construction/dredging monitoring surveys can provide a map of seabed type within an entire survey area based on swath geophysics.
- Comparison of the post-construction survey results with the pre-construction survey results in a GIS environment will allow for the digitization and accurate identification of direct project impacts throughout the entire project area.

Potential Uses
Coastal Monitoring

Indirect Impacts

- Periodic post-construction monitoring surveys can provide multiple, sequential maps of seabed type within an entire survey area based on swath geophysics.
- Comparison of the monitoring survey results with the pre-construction and sequential survey results in a GIS environment will allow for digitization and accurate identification of changing, indirect project impacts throughout the entire project area.

Potential Uses
Coastal Monitoring

Will still require some in-situ quantitative and qualitative diver groundtruthing by qualified marine scientists.

Potential Uses
Coastal Monitoring

- Comprehensive Mapping Product
  - Full swath coverage of the entire project area.
  - 200% overlap of data point coverage.
  - Fully encompasses potential impact areas.
  - Significant increase in available monitoring data.
- Potential Cost Savings
  - Reduced operational weather impacts.
  - No operational turbidity/visibility impacts.
  - Reduced field time requirements.
  - Reduce field staff requirements.

Thank You

Special Thanks to Quester Tangent Corporation for program information and project-specific examples.

ABC Methodology

Seabed File

Confidence

Date Longitude Depth Q2 Class Date

```
20000921,170447863,-123.76734238,49.26566228,-403.44,26.30549240,5.53668976,-49.62476349,99,17,01,CLASS_01,GABNORTH,20000921,0043_165202,2,12987
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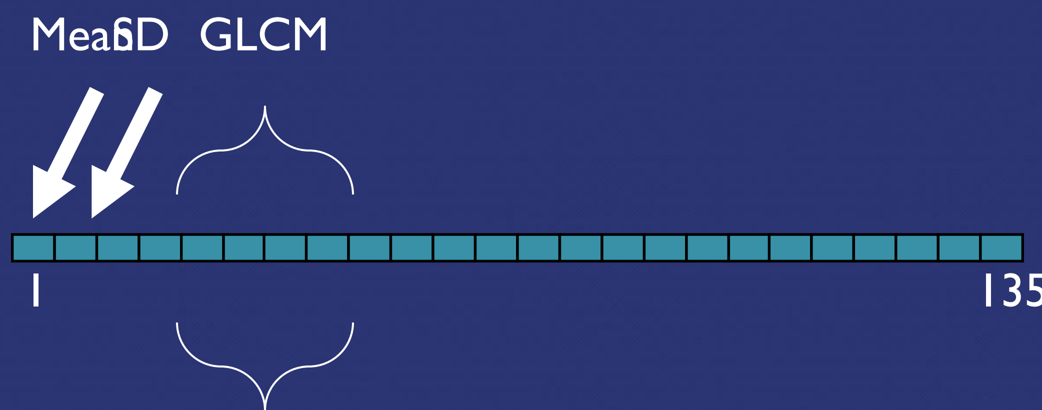
Time Latitude Q1 Q3 Survey Line DSN

Probability

ABC Methodology
FFVs



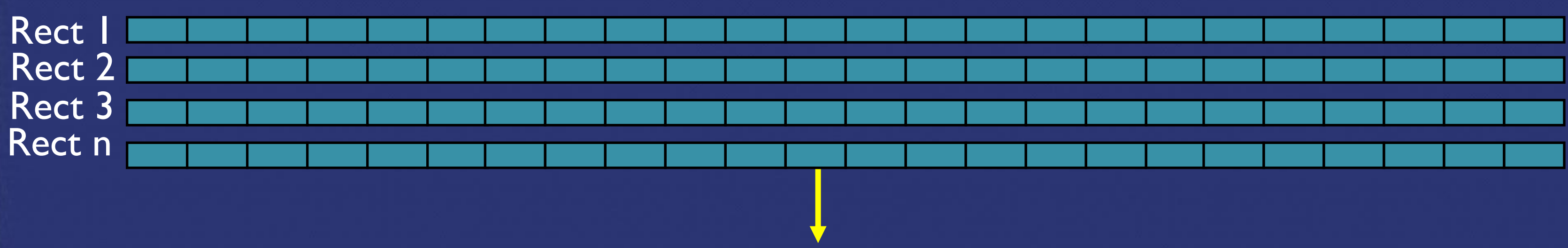
FULL FEATURE VECTOR (FFV)

ABC Methodology

FFVs

Data Reduction:

Each FFV String reduced to three Principal Components using PCA



Rect 1 - Q1, Q2, Q3
Rect 2 - Q1, Q2, Q3
Rect 3 - Q1, Q2, Q3
Rect n - Q1, Q2, Q3