23rd Annual National Conference on Beach Preservation Technology

Monitoring of a Core-Loc ® Breakwater in Lanai, Hawaii

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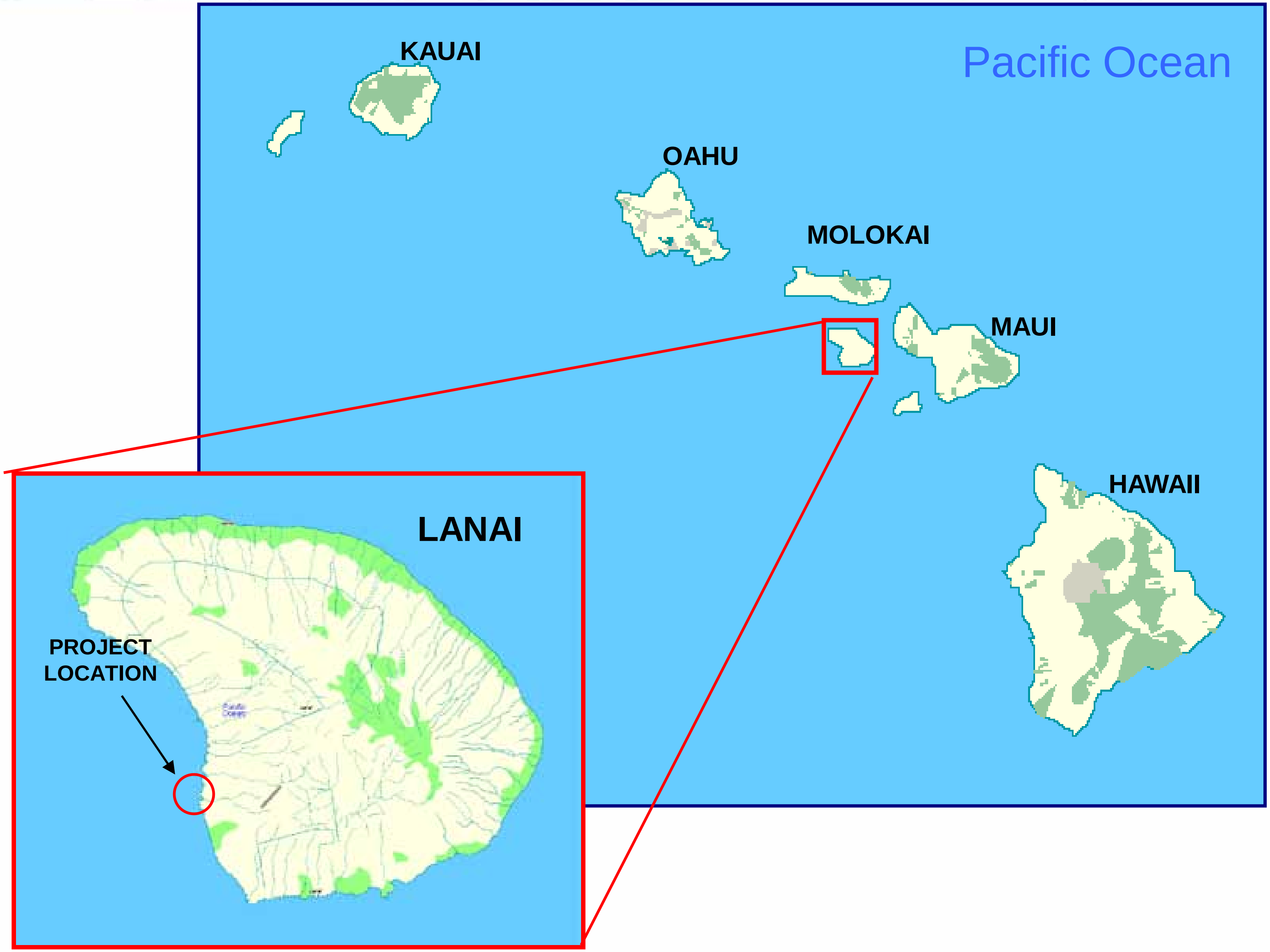
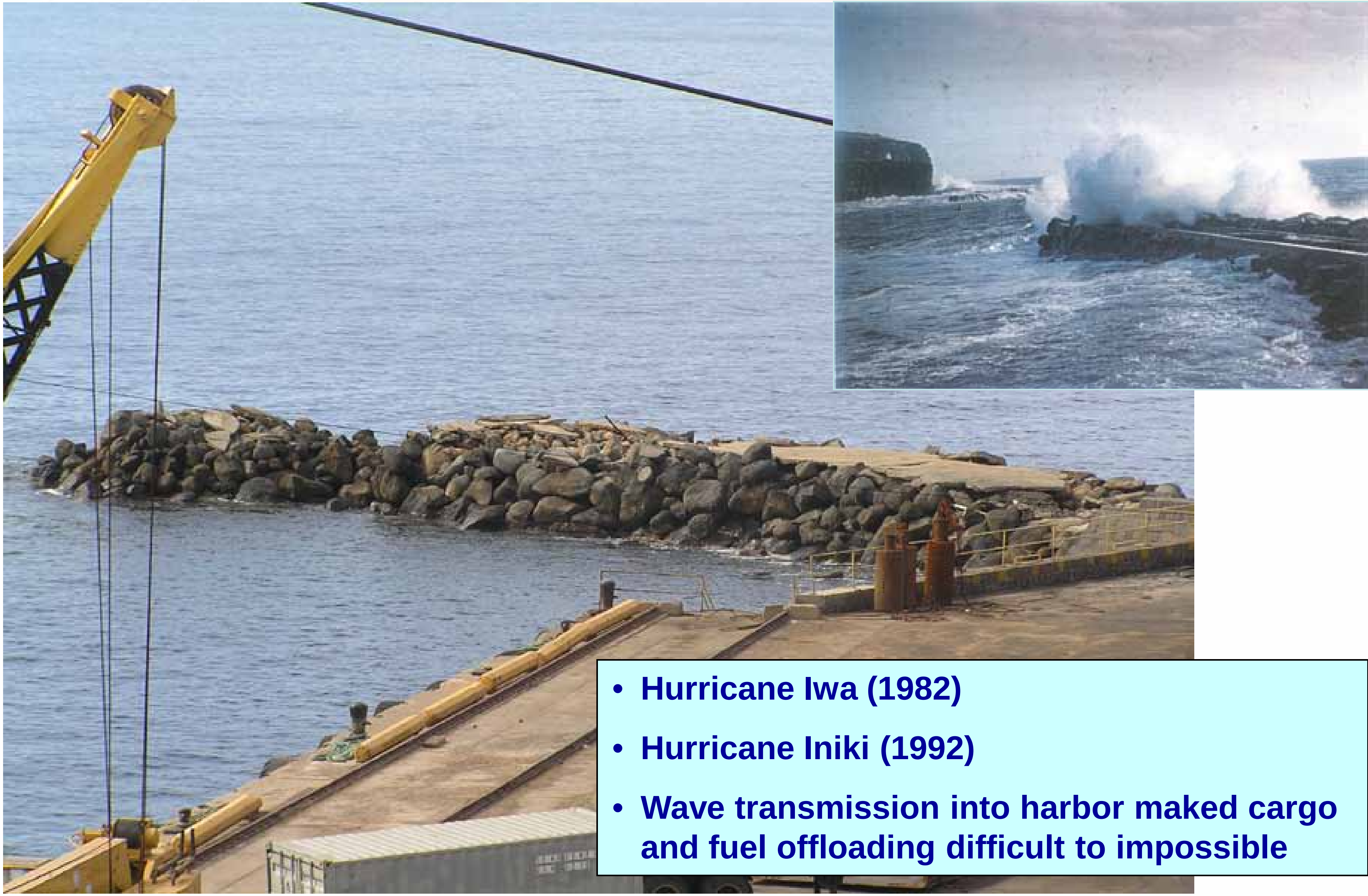
Presentation Outline

- Project Background
- Breakwater Design
- Construction Methods
- Monitoring Program Activities
- Monitoring Summary
- FY10 Activities

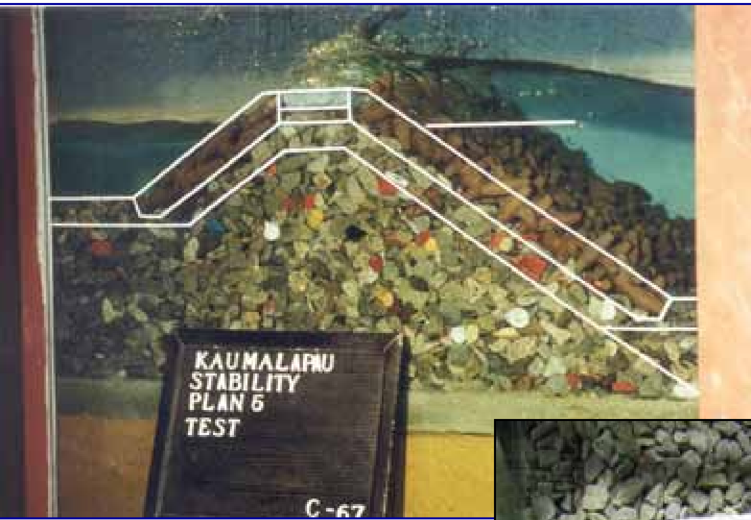

KAUAI
Pacific Ocean
OAHU
MOLOKAI
MAUI
HAWAII
LANAI
PROJECT
LOCATION

- Constructed in 1925 by the Hawaiian Pineapple Company (Dole Company)
- Rubblemound from nearby quarries and field stone
- Ownership transferred to HDOT in July 2000
- Only commercial harbor supporting all 3,000 island residents and tourism industry



- **Hurricane Iwa (1982)**
- **Hurricane Iniki (1992)**
- **Wave transmission into harbor maked cargo and fuel offloading difficult to impossible**

Physical and Numerical Modeling



ERDC Physical Models

Physical Models:

- Operational Harbor Conditions
- Breakwater Stability
- Core-Loc ® Strength and Interlocking
- Armor Unit Packing Density

Numerical Models:

- Wave Transformation
- Wave Data Collection
- Identify Harbor Alternative Layouts for Physical Modeling
- Harbor Oscillation

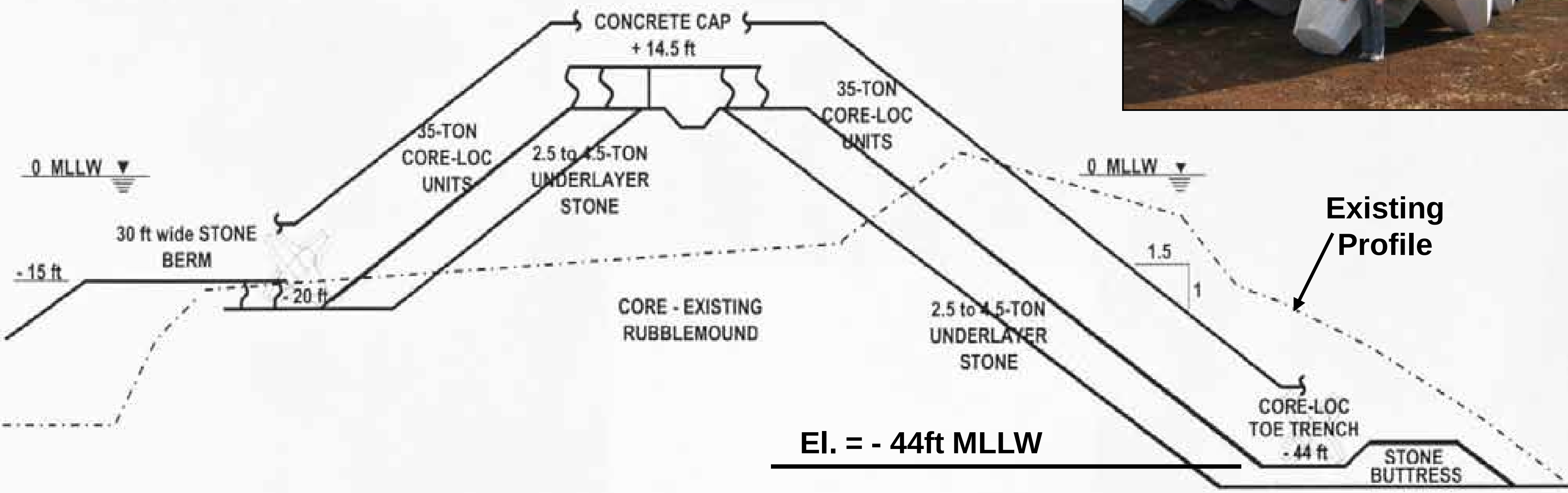
Design Considerations

- Deepwater Toe Foundation at depths of up to 60 feet
- Original Structure of Rock, Concrete Armor Units and Debris
- Storm Wave Height of 30+ feet
- Required Armor Stone Size Unavailable in Hawaii => Core-Loc® Concrete Armor Units Chosen

Typical Design Cross-Section

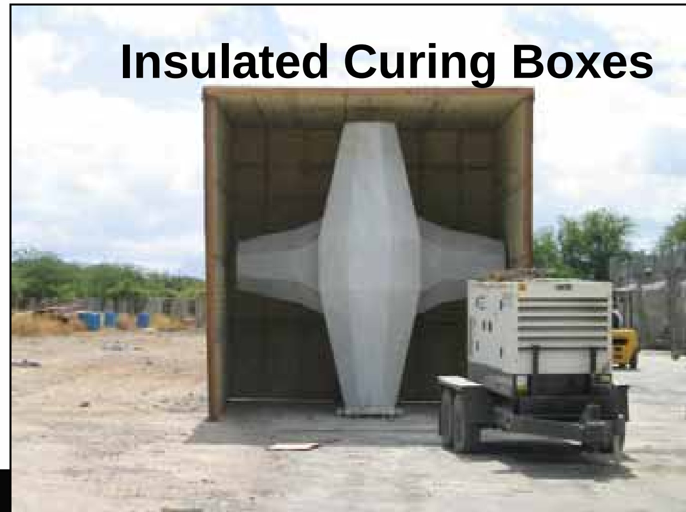
Design Wave ~ 30+ feet , 12 seconds (Hurricane Conditions)

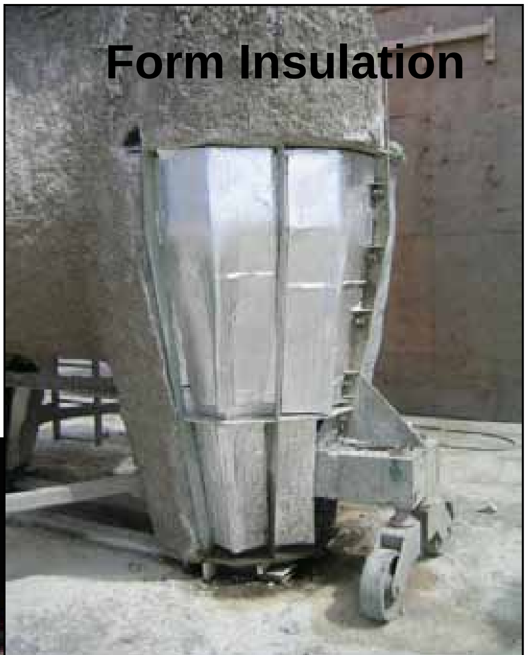
Model Stability Tests indicate 35-ton Core-Locs ® required



Construction Methods


Core-Loc Forms


Insulated Curing Boxes


Form Insulation


Casting at Night

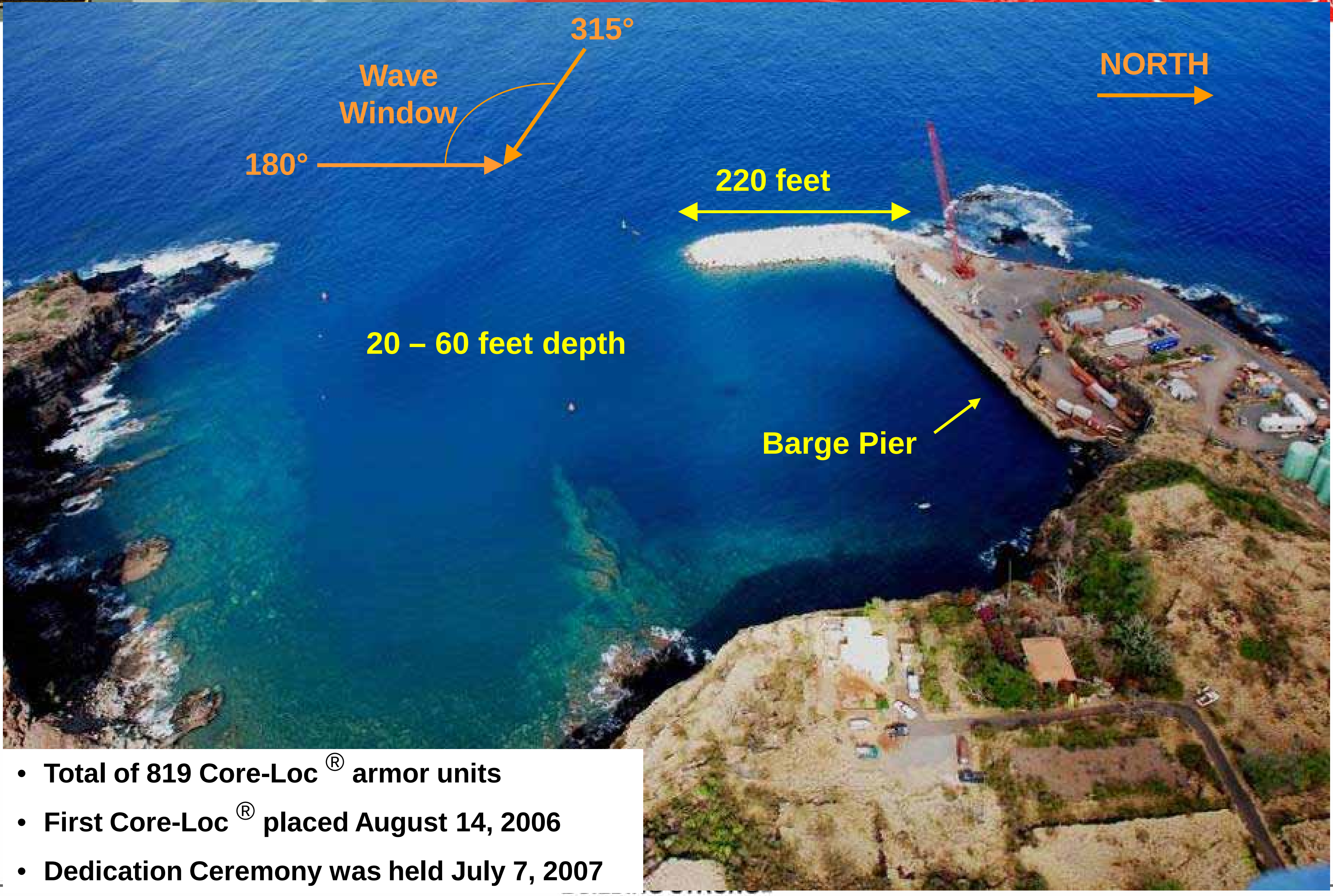
Construction Methods
Core-Loc® Placement Plan

Construction Methods

GPS Tolerance = 38cm

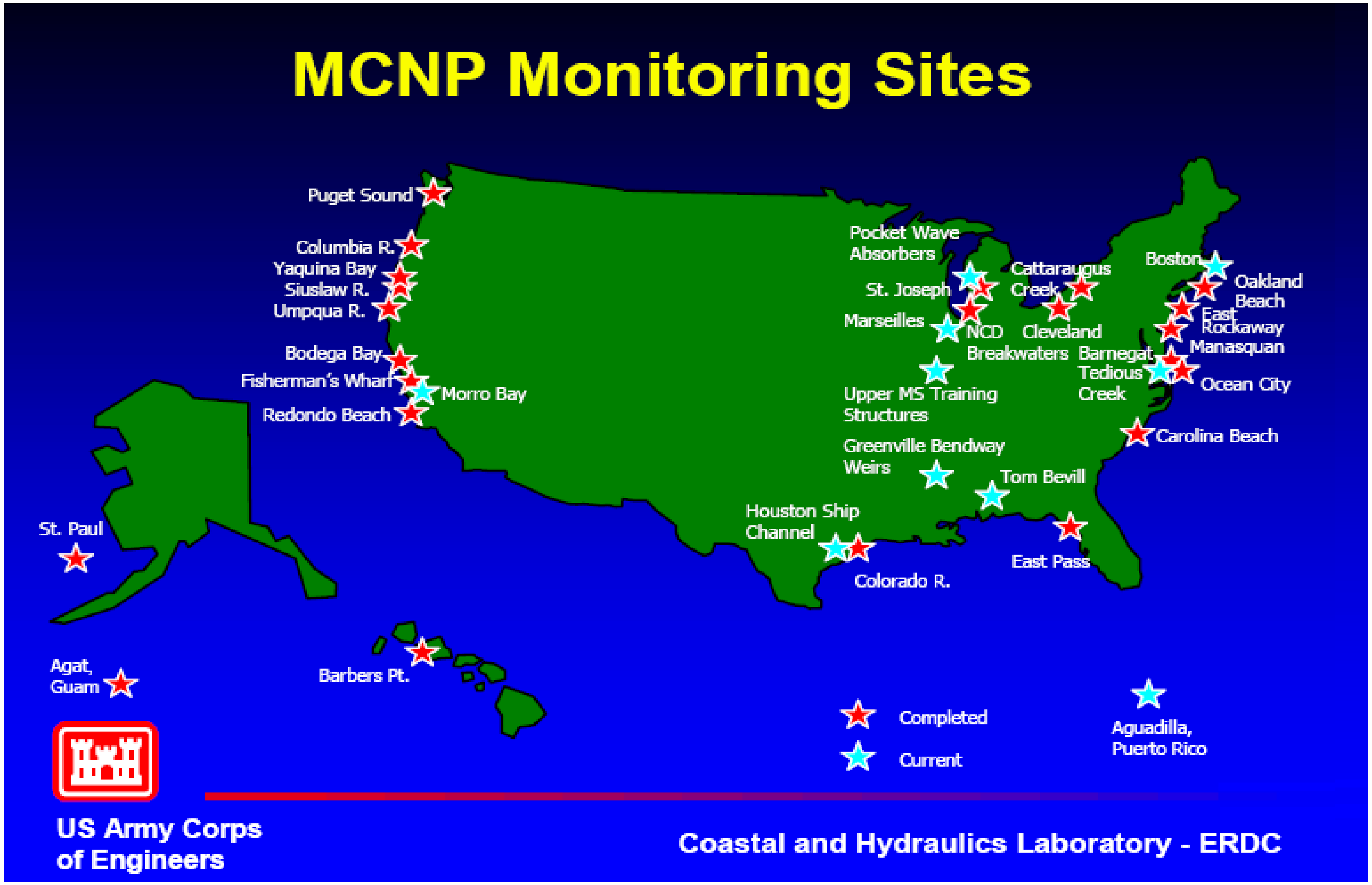
Packing Density = 0.62

Random Orientation



- Total of 819 Core-Loc ® armor units
- First Core-Loc ® placed August 14, 2006
- Dedication Ceremony was held July 7, 2007

USACE Monitoring of Completed Navigation Projects (MCNP) Program



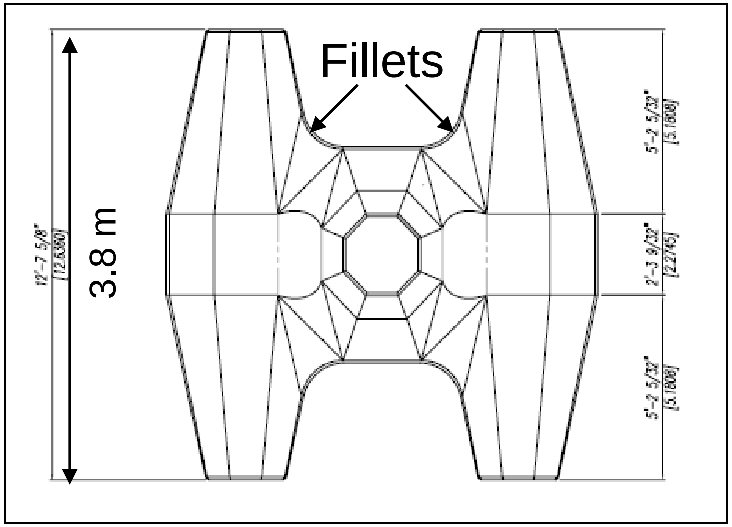
Structure Monitoring

Monitoring Goals at Kaumalapau Harbor:

- Gather Strength Data for Core-Loc ® Armor Units
- Evaluate effectiveness of Breakwater in Reducing Wave Energy at Barge Pier
- Monitor Post-construction Breakwater Settlement including Concrete Cap
- Develop Methods for Monitoring Armor Layers

Structure Monitoring

Strength Testing of Core-Loc II ®

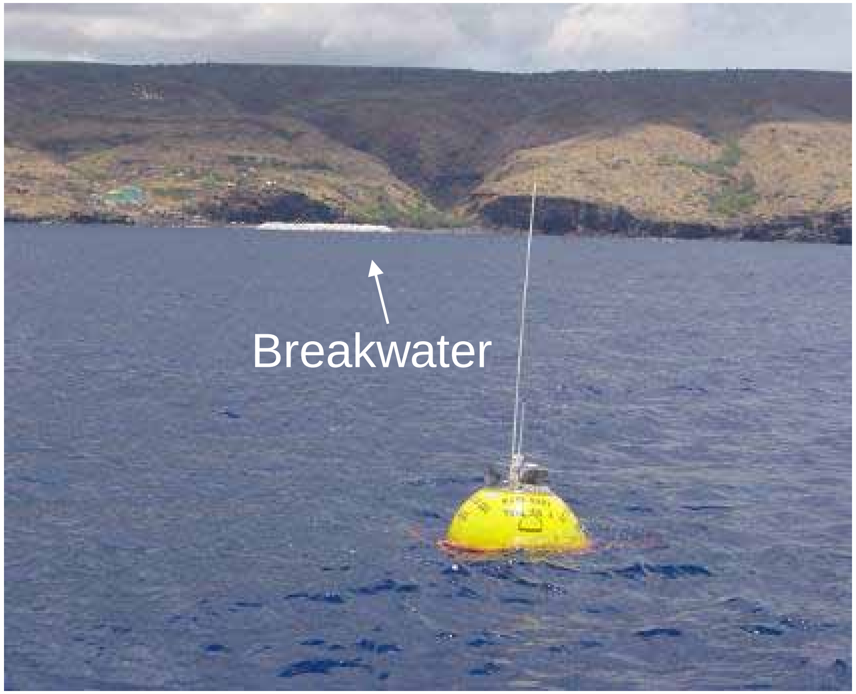


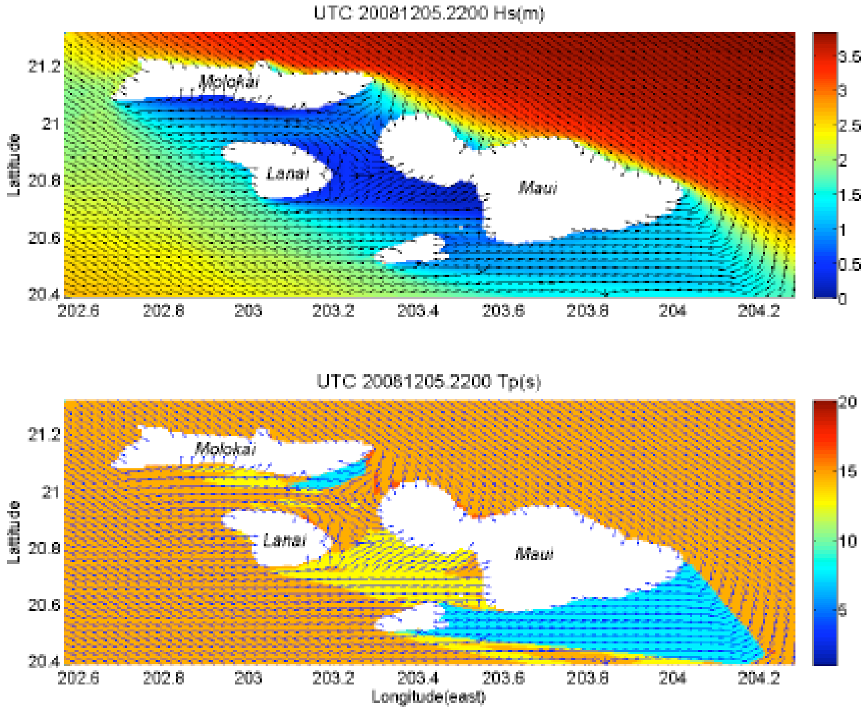
- Loaded with six 50-kip hydraulic rams between legs
- Created flexural tensile load to interior saddle of unit, compressive load to exterior
- Load monitored with load cells and strain gages

Structure Monitoring

Post-Construction Wave Transmission into Harbor

CDIP 146 Wave Buoy with Breakwater in Background





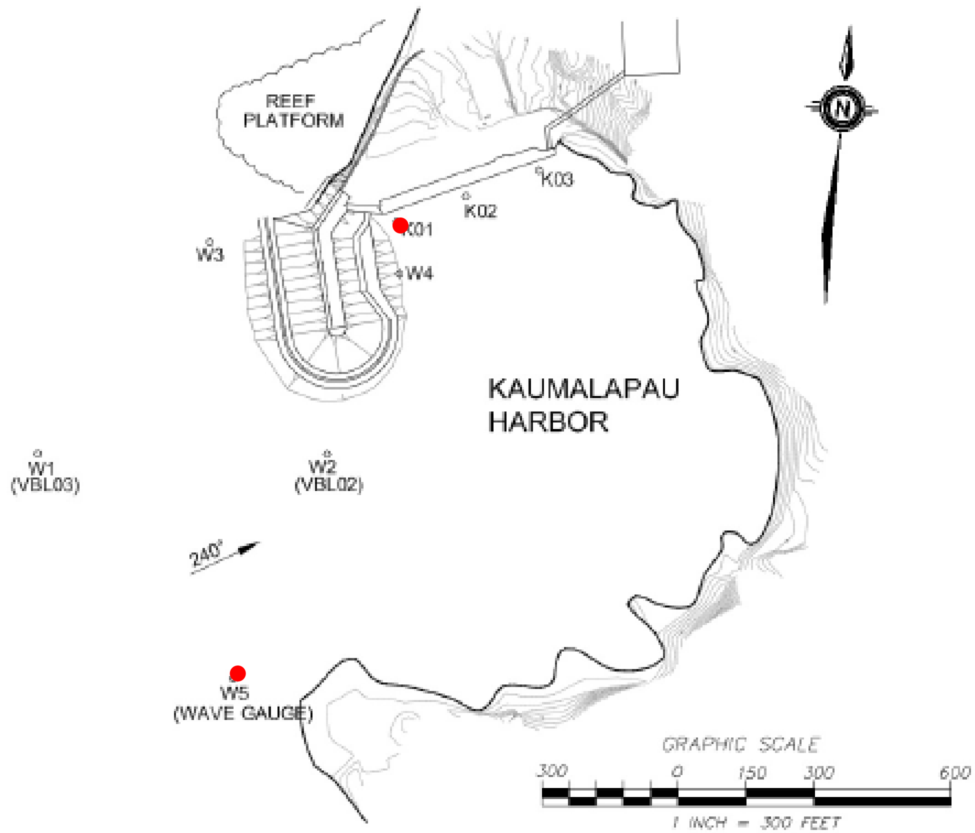
Wave Models SWAN and REF/DIF for Transformation to Harbor

Structure Monitoring

Post-Construction Wave Transmission into Harbor

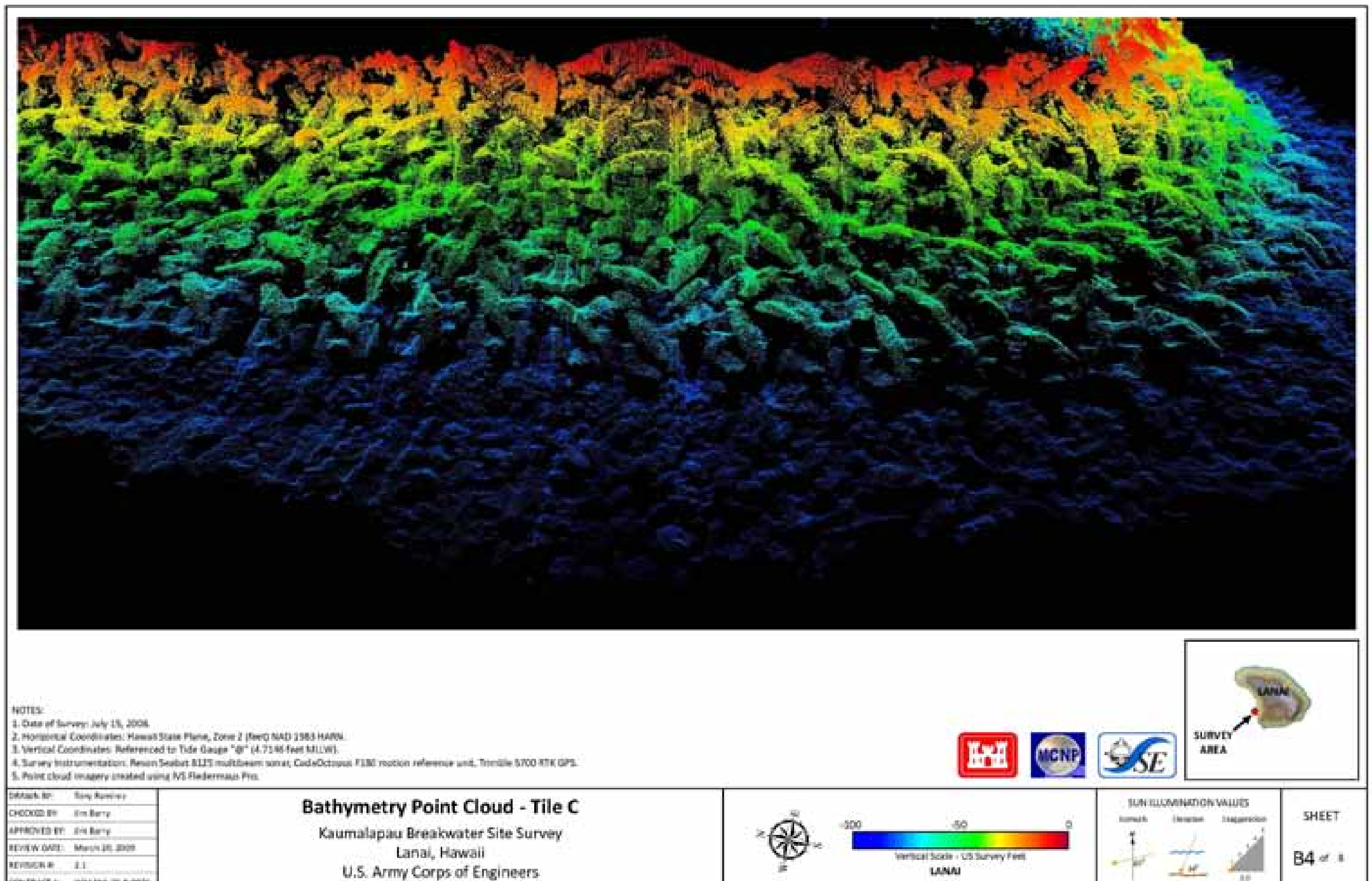
CDIP 146 Buoy

- **Wave Models calibrated using CDIP 146 and temporary wave gauge data**
- **Developed a 'lookup table' to correlate buoy measurements to virtual locations in the harbor**
- **Program developed to automate lookup tables: KPWAVE**



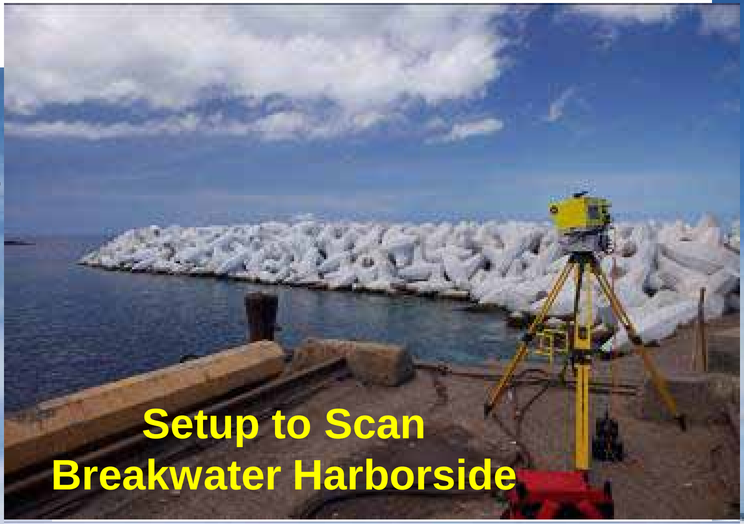
Structure Monitoring

Breakwater Multi-beam Survey



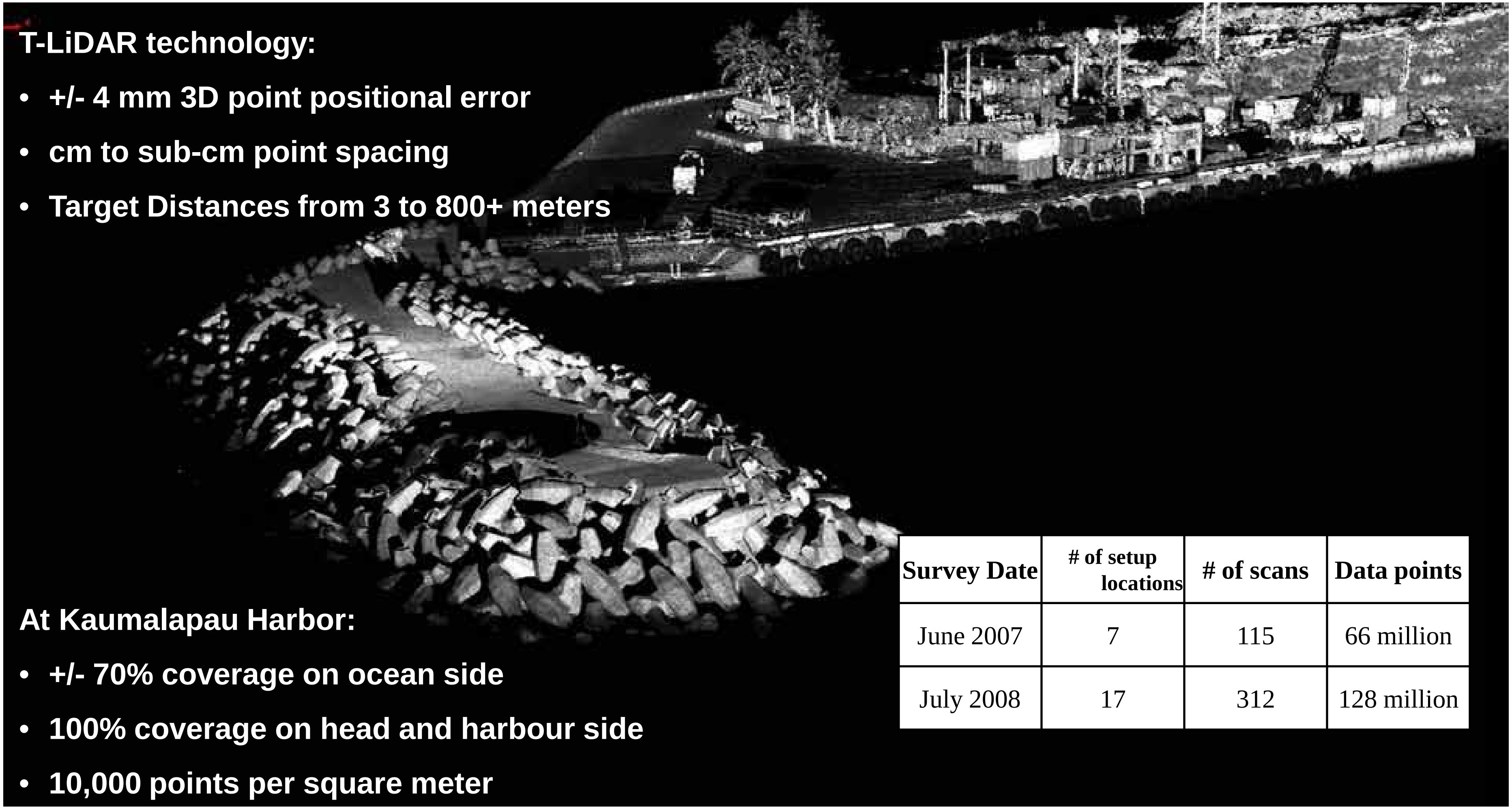
Structure Monitoring

Breakwater Settlement Measurements using T-LiDAR



Structure Monitoring

Breakwater Settlement Measurements using T-LiDAR



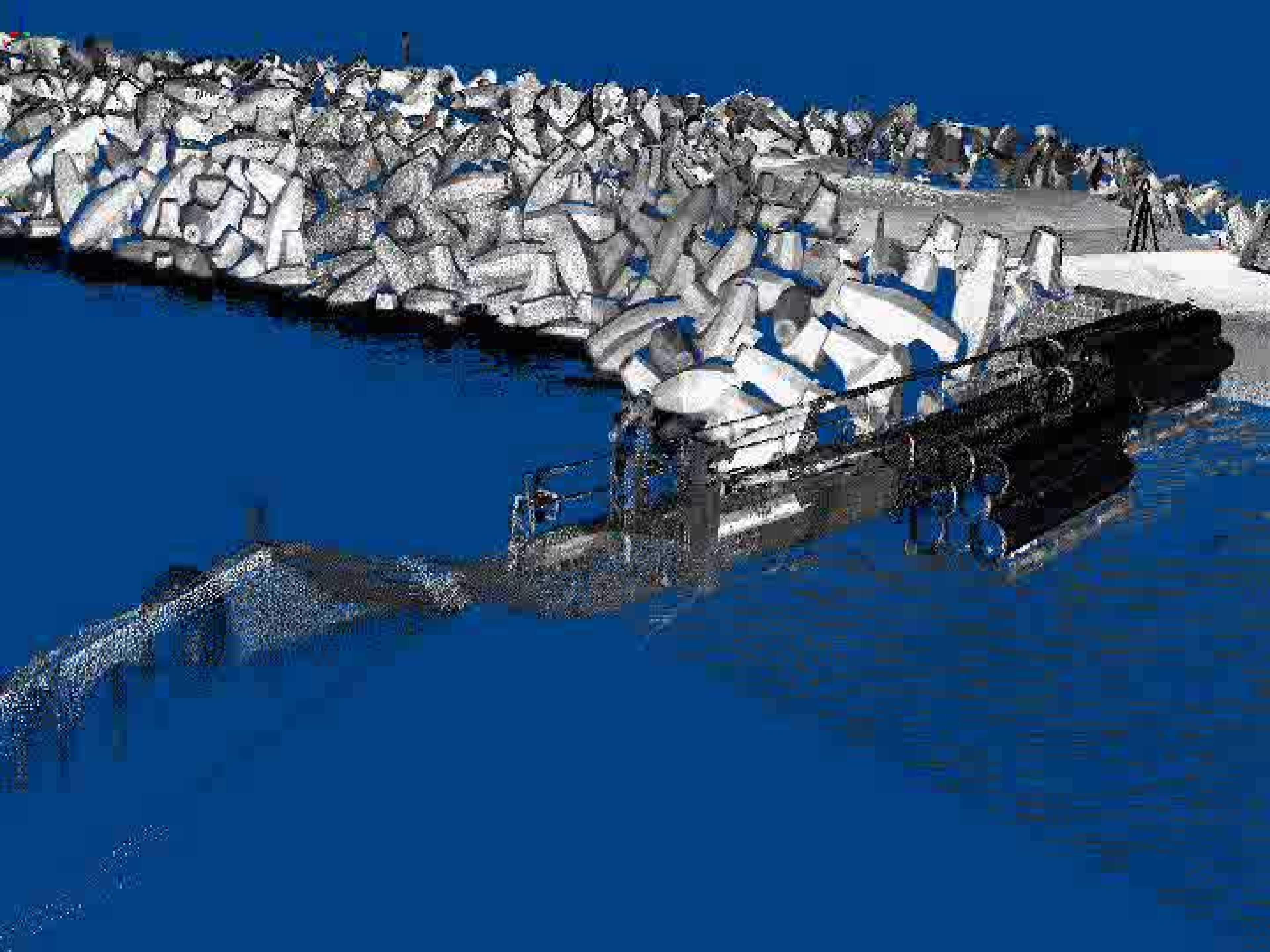
T-LiDAR technology:

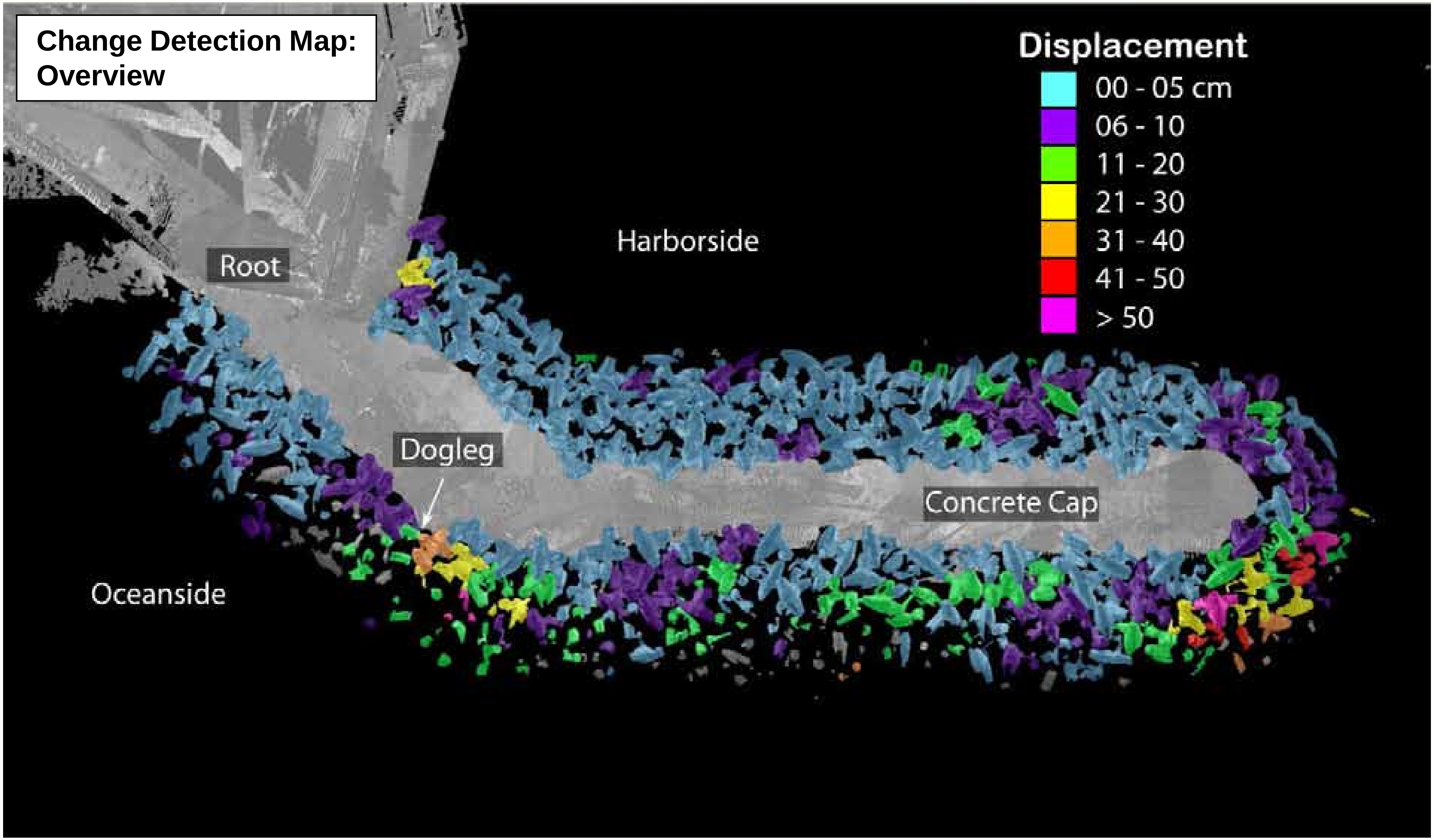
- +/- 4 mm 3D point positional error
- cm to sub-cm point spacing
- Target Distances from 3 to 800+ meters

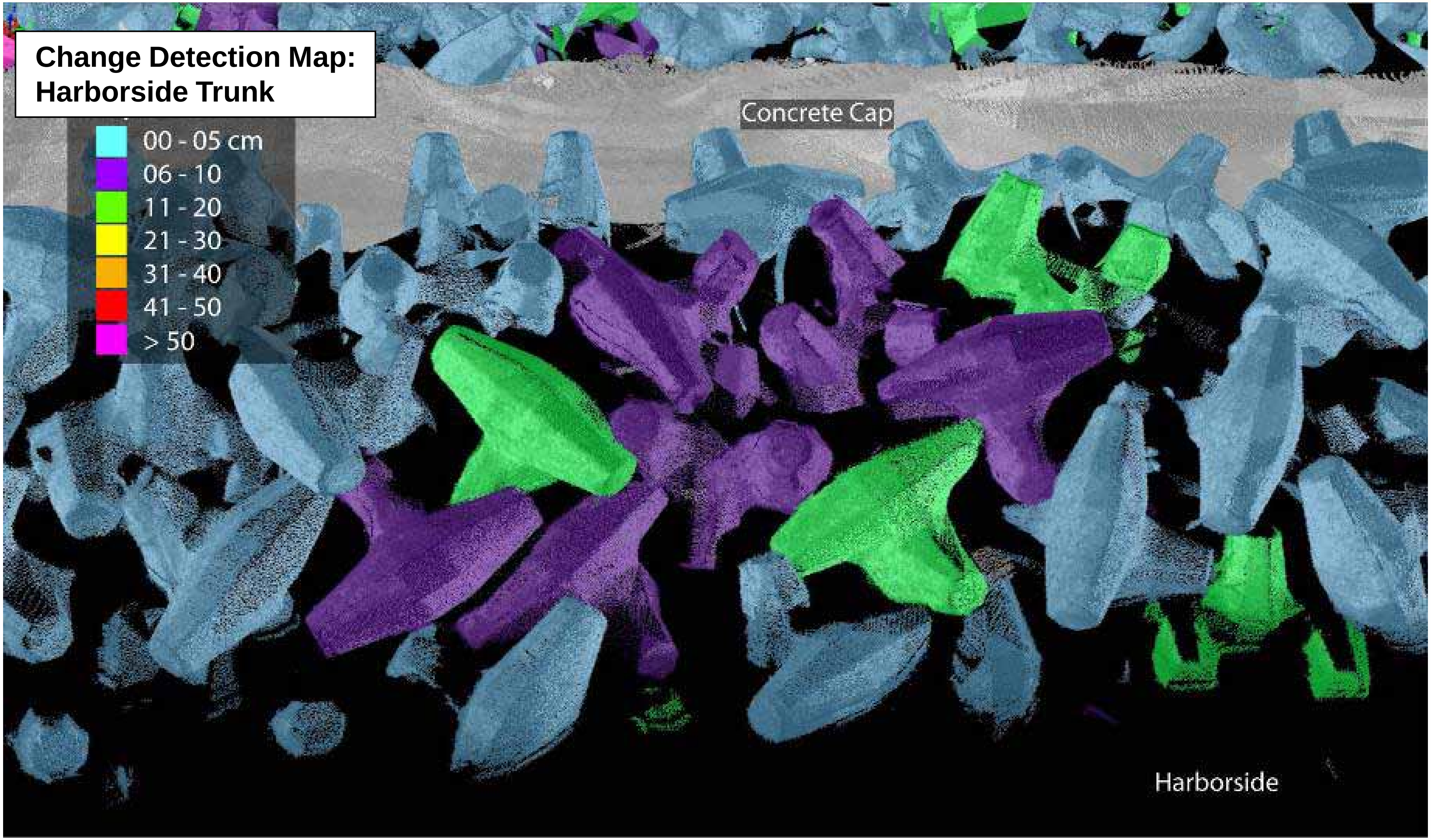
At Kaumalapau Harbor:

- +/- 70% coverage on ocean side
- 100% coverage on head and harbour side
- 10,000 points per square meter

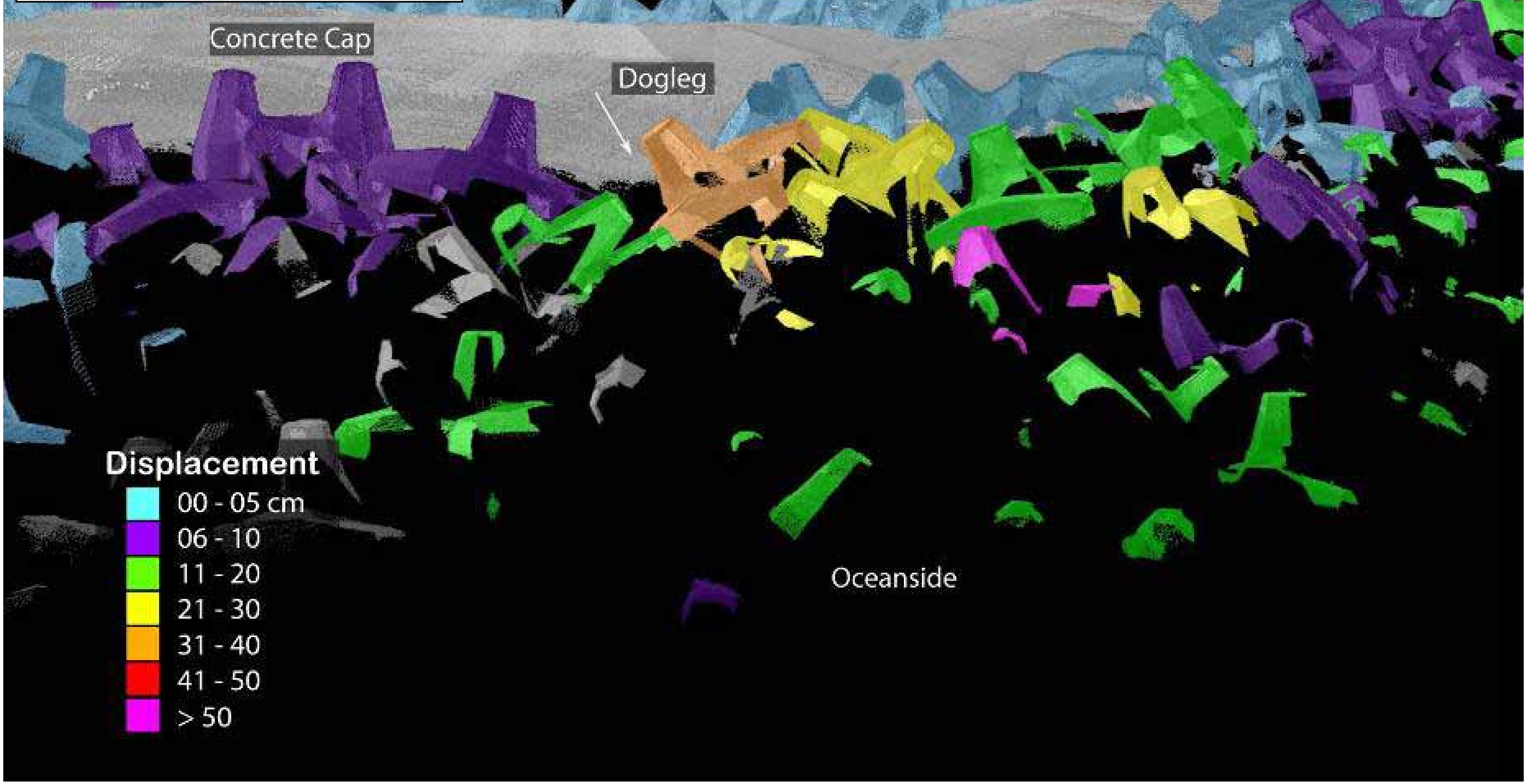
Survey Date	# of setup locations	# of scans	Data points
June 2007	7	115	66 million
July 2008	17	312	128 million

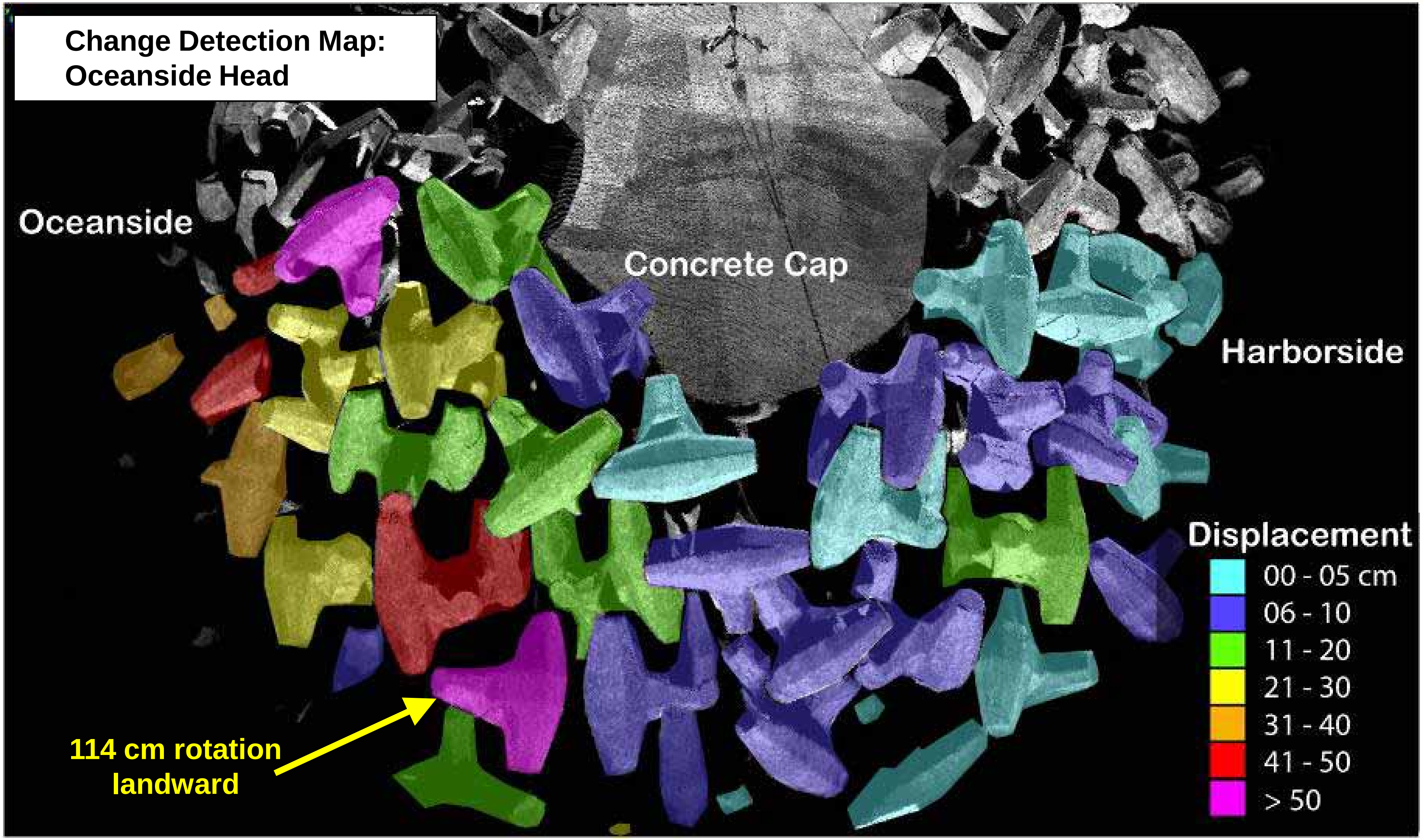



Change Detection Map: Overview
Displacement
00 - 05 cm
06 - 10
11 - 20
21 - 30
31 - 40
41 - 50
> 50
Harborside
Root
Dogleg
Concrete Cap
Oceanside

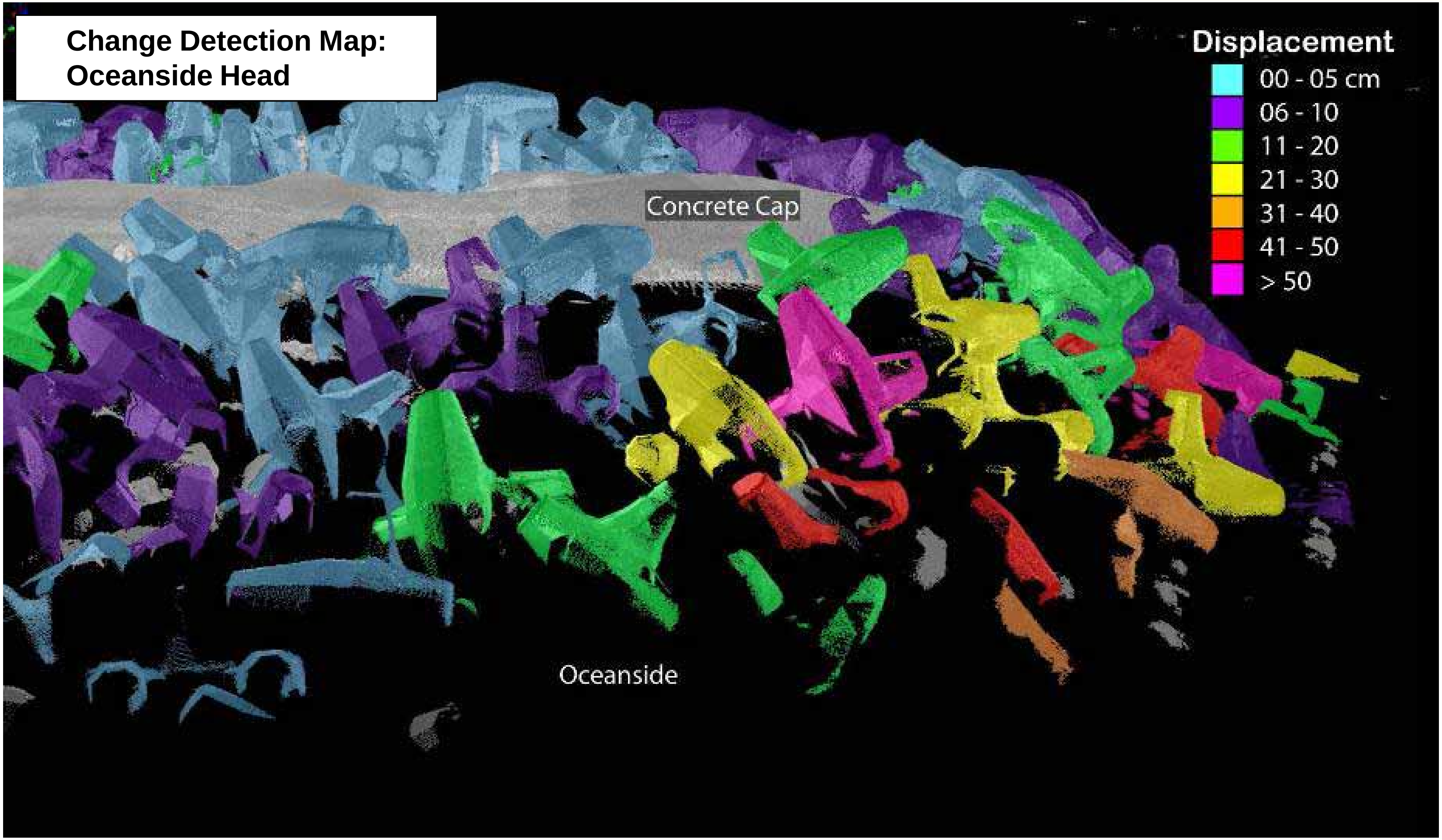

Change Detection Map:
Harborside Trunk
00 - 05 cm
06 - 10
11 - 20
21 - 30
31 - 40
41 - 50
> 50
Concrete Cap
Harborside

Change Detection Map: Dogleg




Change Detection Map:
Oceanside Head
Oceanside
Concrete Cap
Harborside
Displacement
00 - 05 cm
06 - 10
11 - 20
21 - 30
31 - 40
41 - 50
> 50
114 cm rotation
landward

Change Detection Map: Oceanside Head



Structure Monitoring

Finding of T-LiDAR Surveys

- Movement of 279 armor units was measured over a period of one year
- 75% of the units moved less than 10 cm
- Areas of greatest movement were noted at structure bends (due to reduced packing density and interlocking)
- Maximum movement of 114 cm measured at breakwater head
- No damage to concrete cap or broken units noted
- Satisfactory structure performance to date

Structure Monitoring

T-LiDAR Advantages

- Rapid Data Collection
- Low Cost
- High Resolution
- Increased Accuracy
- Enables Precise Change Detection

T-LiDAR Disadvantages

- Large Data Sets
- Intense Data Processing
- Problematic for Long Structures
- Can't Penetrate Water Surface
- Limited to Line-of-Sight data acquisition

Monitoring Summary

Gather Strength Data for Core-Loc® Armor Units

- Measured Concrete Strength
- Placed 30 Concrete Cylinders Underwater for Future Strength Tests
- Documented Cylinder Testing done during Construction

Breakwater Settlement and Monitoring Armor Layers

- Completed two T-LiDAR Surveys to Determine 1-year Settlement
- Conducted Underwater Multi-beam Survey
- Conducted Visual Inspections of Structure
- Surveyed Toe Stability Using ROV

Wave Transmission into Harbor

- Installed Offshore Wave Buoy
- Deployed/Retrieved Wave Gages and Analyzed Wave Data
- Correlated Buoy/Gage Data using Wave Models
- Developed Wave Transformation Lookup Tables and KPWAVE

FY10 Activities

- Determine 3D position change of unit centroid as well as surface rotation and translation magnitudes
- Compare unit centroid position to original placement plan/as-built condition
- Correlate long-term armor unit movement to wave records
- Assess Pre- and Post-event structure damage
- Combine LiDAR and multi-beam survey acquisition on floating platform for full structure coverage
- Prepare Monitoring report

Acknowledgements

USACE MCNP Program

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US Geological Survey

US Army Corps
of Engineers


Thank You
US Army Corps
of Engineers
MCNP