RELIC TO RESILIENCE
THE GLASS BREAKWATER REPAIR PROJECT

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August 5, 2026

The Glass Breakwater - Apra Harbor, Guam

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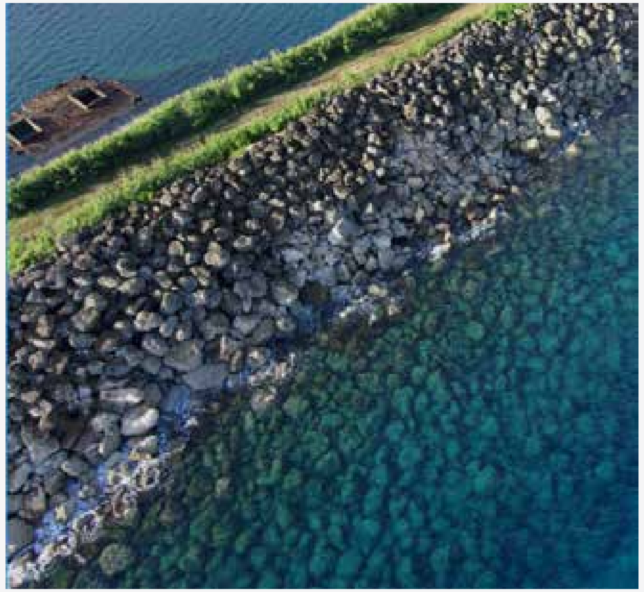


- Breakwater protects Port of Guam + Naval Base Guam
- Typhoon Mawar (May 2023) caused severe damage

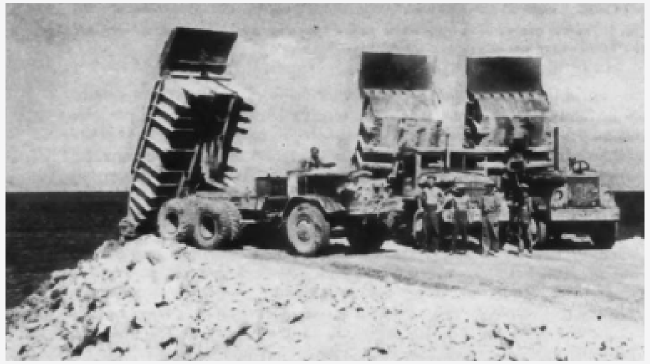
à Apra Harbor Waterfront Repair Project

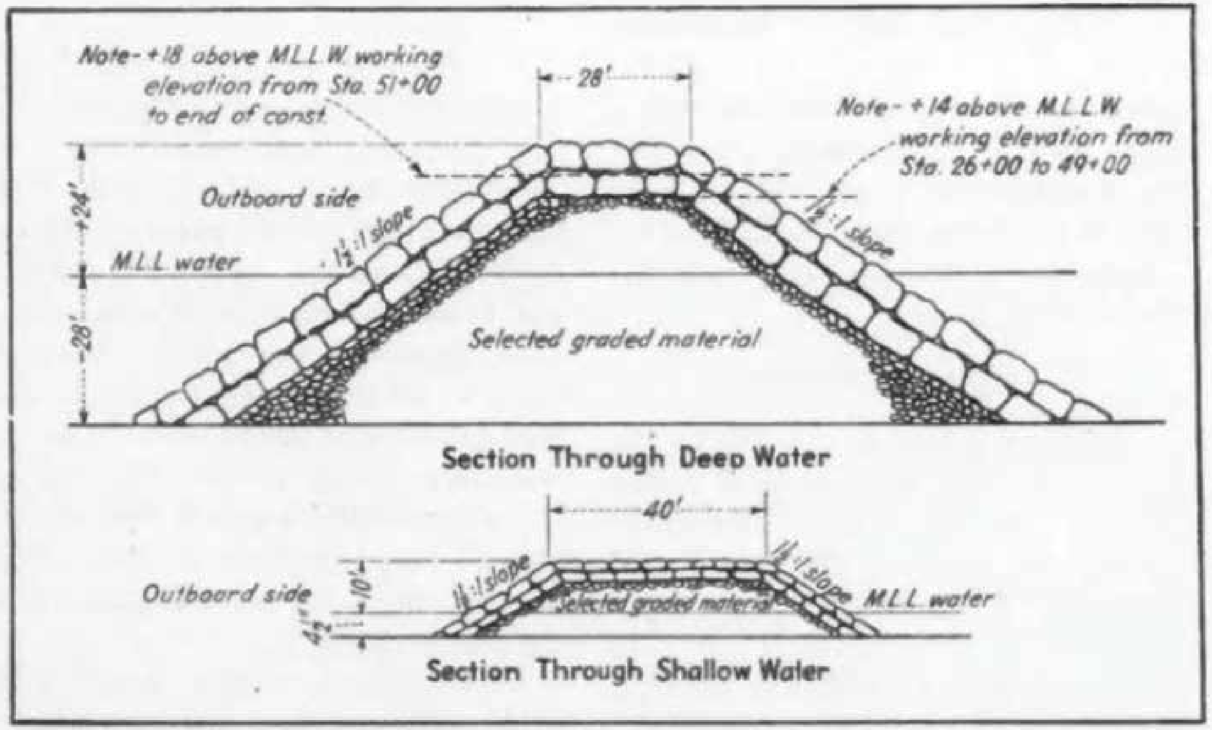
- $571M design-build project (NAVFAC)
- Comprehensive repair of outer 5,800 ft of breakwater
- Contractor - TPC-NAN JV (**Black Construction**)
- Designer - **Baird** (+ AECOM, SEI, Woolpert, CLI, NRC)

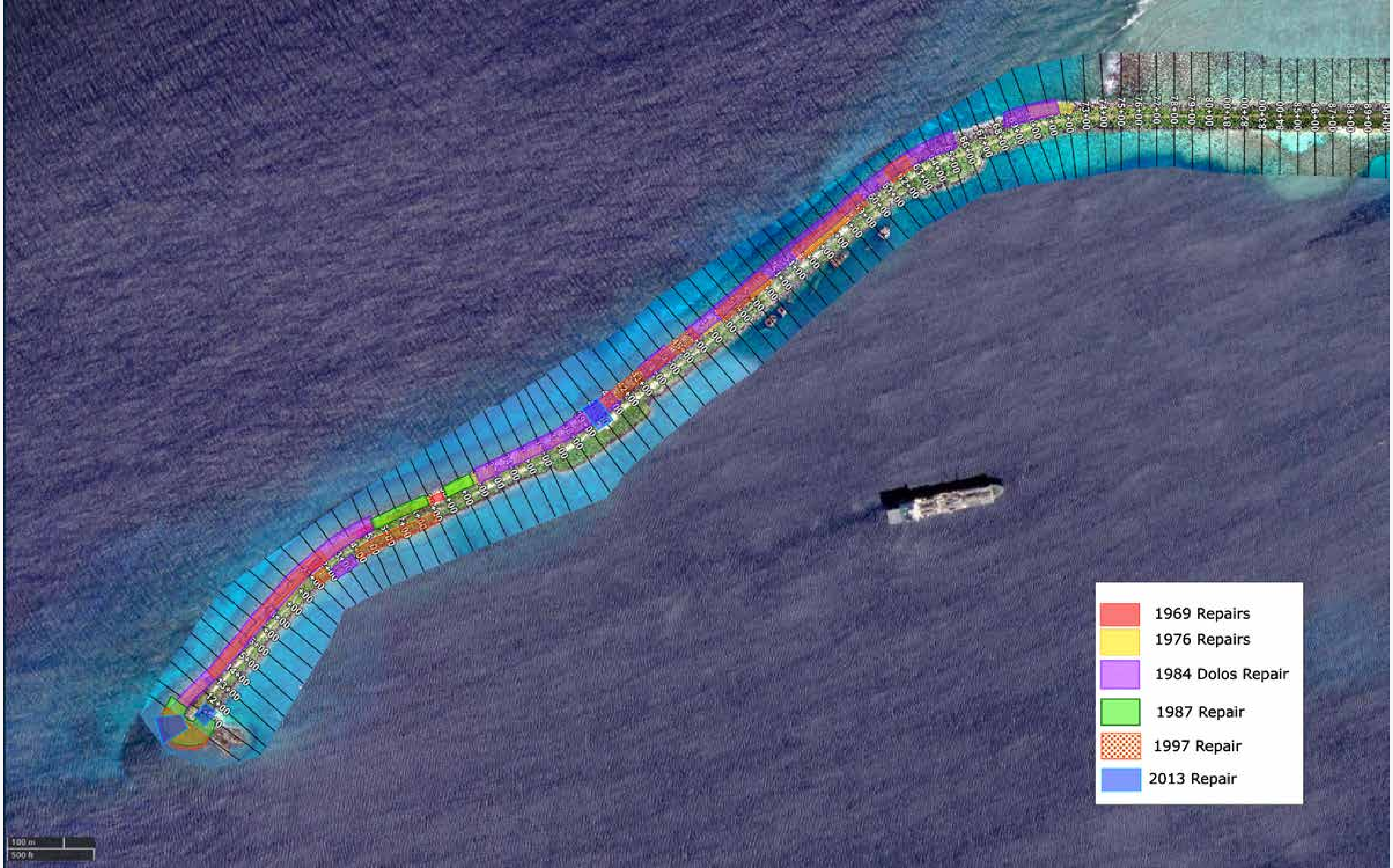
NAVFAC Naval Facilities Engineering Command | Tutor Perini Corporation | Nan Inc | Black Construction Corporation | Baird. Innovation Engineered. | SE Sea Engineering, Inc. | AECOM | WOOLPERT Architecture | Engineering | Geospatial | CLI

Original Design + Construction

- Construction started in 1941, completed in 1944-46 (Seabees)
- Total length ~ 2.8 miles, depth up to 36 ft
- ~ 2M cy of rock fill from local quarry
- ~ 10-30 T armor stone
- Harbor played major role in late WWII

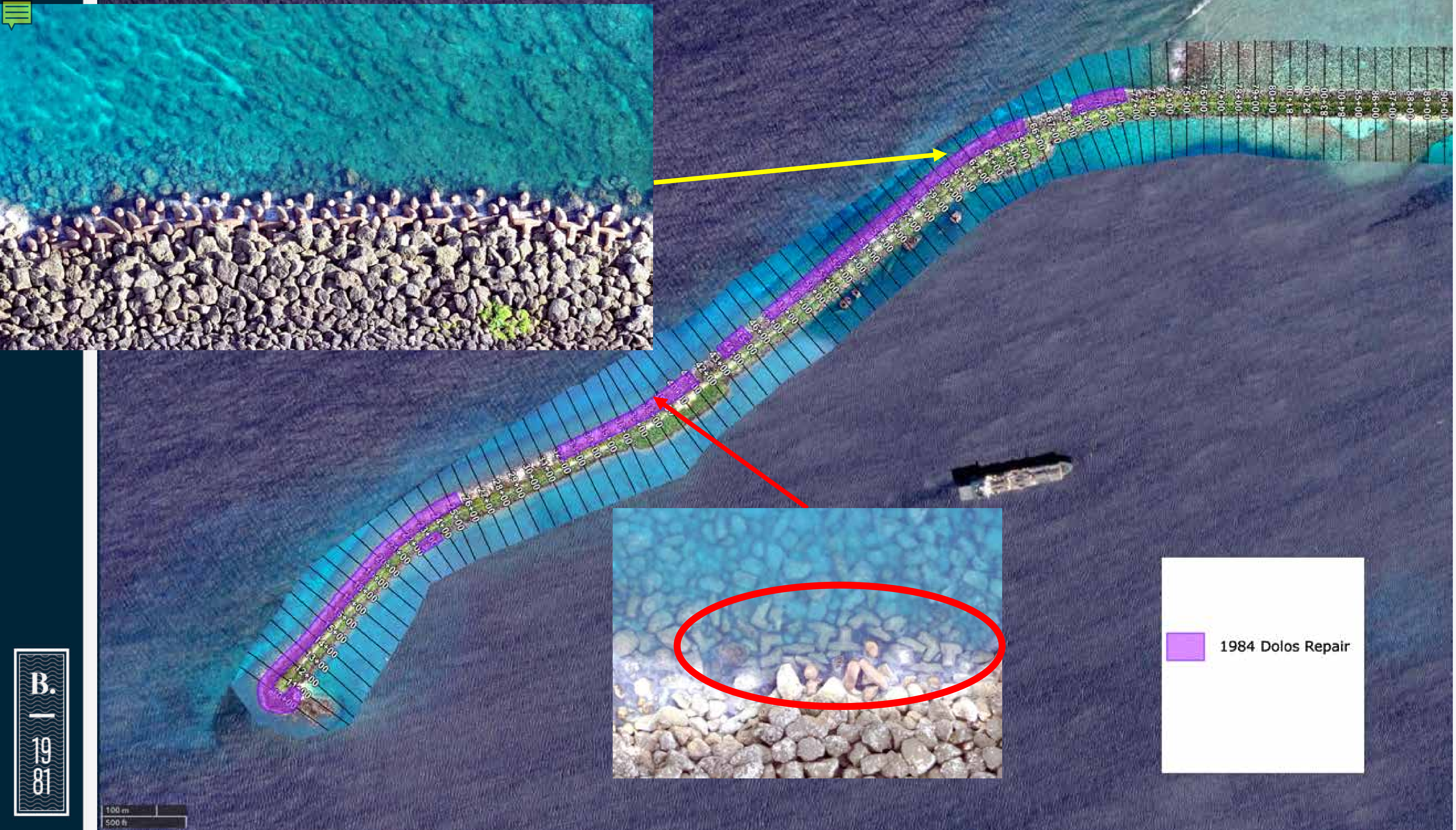





1969 Repairs
1976 Repairs
1984 Dolos Repair
1987 Repair
1997 Repair
2013 Repair
100 m
500 ft


1969 Repairs
100 m
500 ft

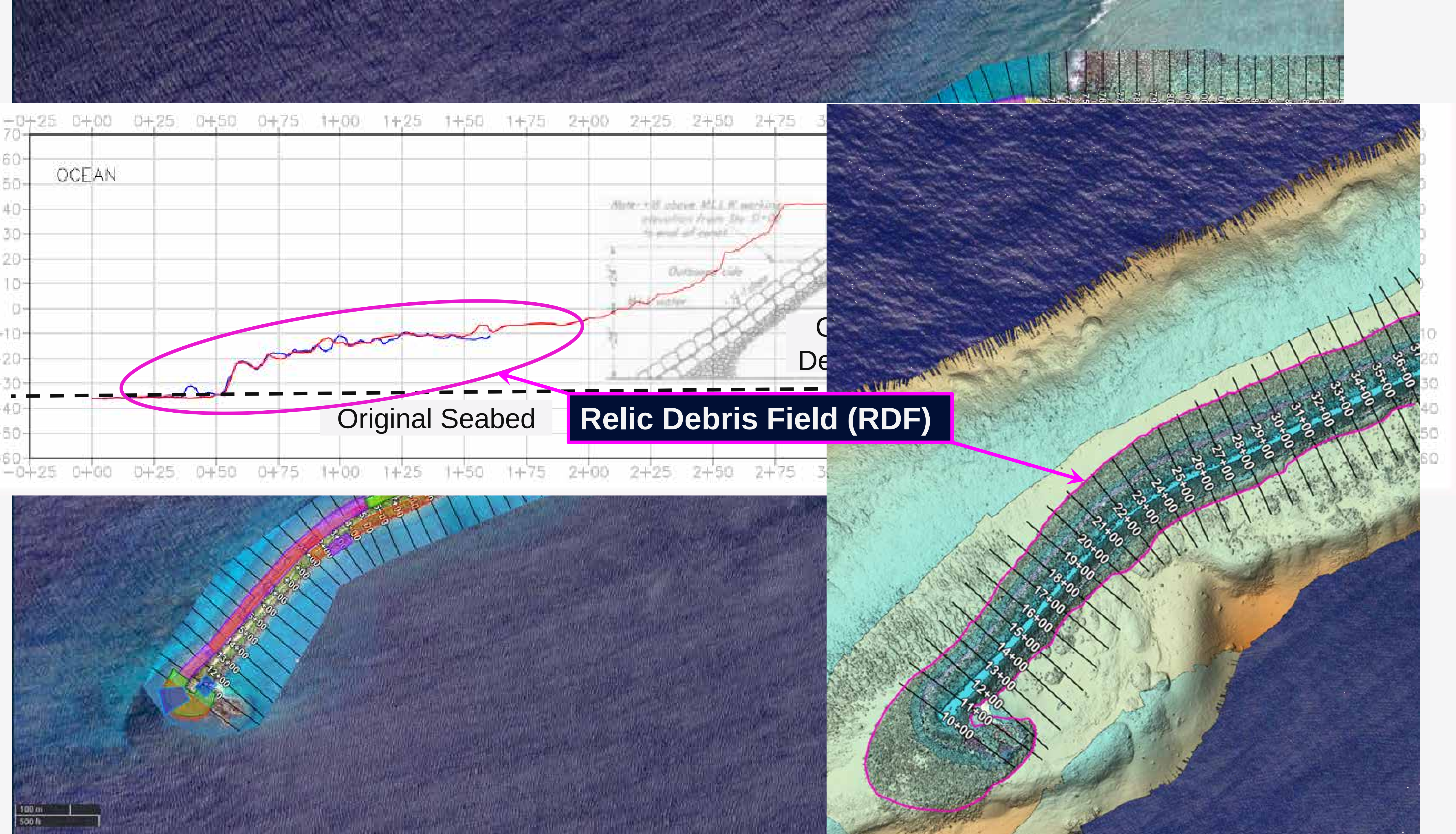

1976 Repairs
100 m
500 ft


1984 Dolos Repair
100 m
500 ft

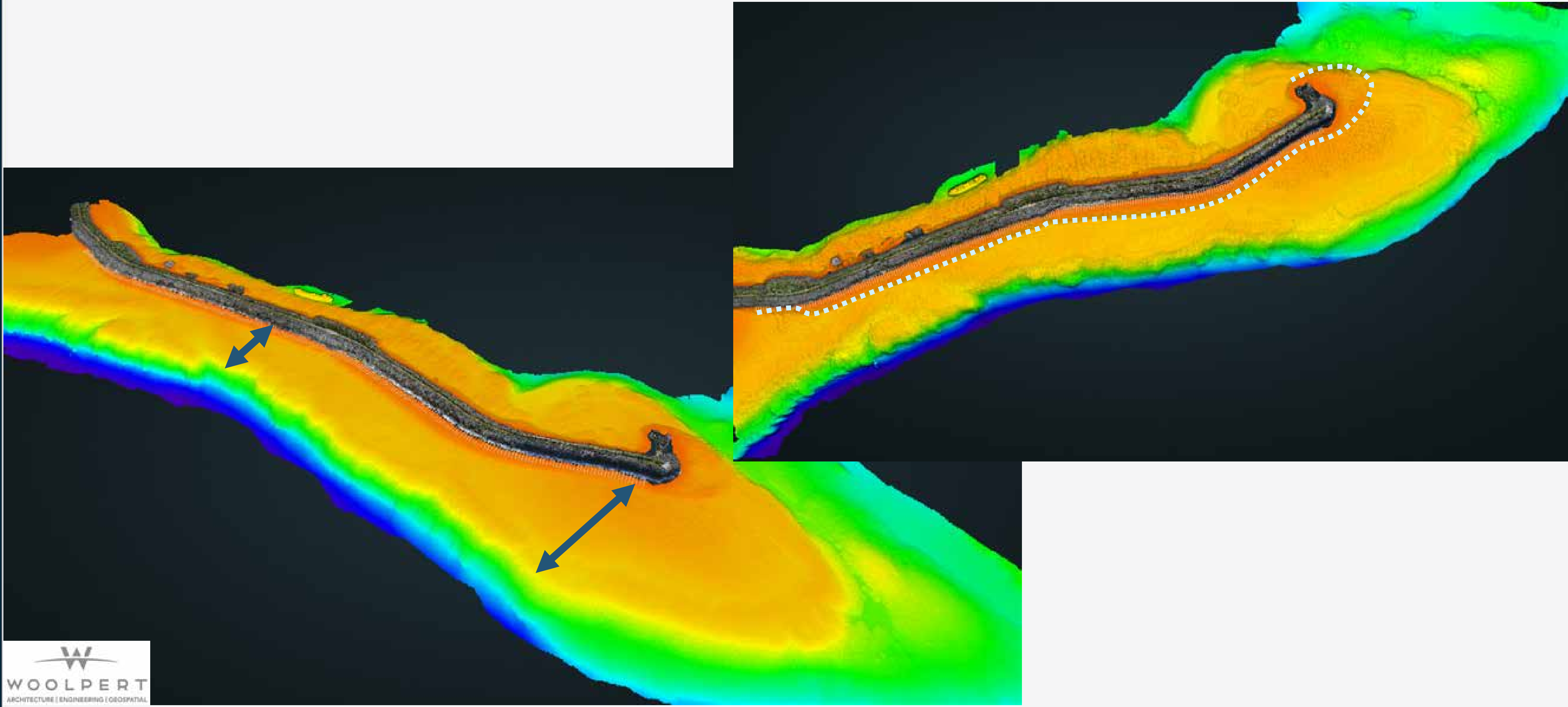

1987 Repair
100 m
500 ft


1997 Repair
100 m
500 ft

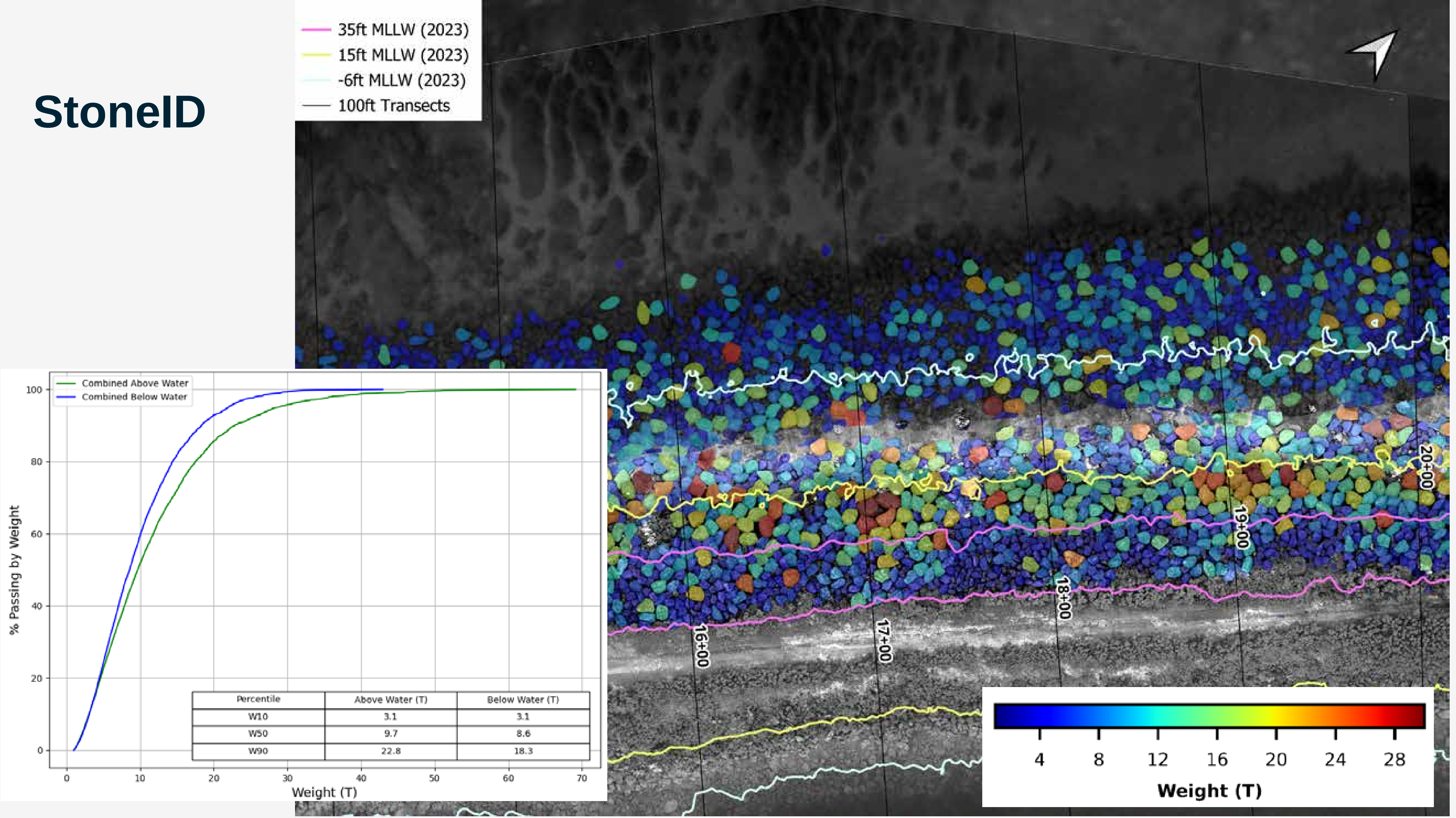

2013 Repair
100 m
500 ft


OCEAN
Original Seabed
Relic Debris Field (RDF)
-0+25 0+00 0+25 0+50 0+75 1+00 1+25 1+50 1+75 2+00 2+25 2+50 2+75
70 60 50 40 30 20 10 0 -10 -20 -30 -40 -50 -60
10+00 11+00 12+00 13+00 14+00 15+00 16+00 17+00 18+00 19+00 20+00 21+00 22+00 23+00 24+00 25+00 26+00 27+00 28+00 29+00 30+00 31+00 32+00 33+00 34+00 35+00 36+00

Site Characterization



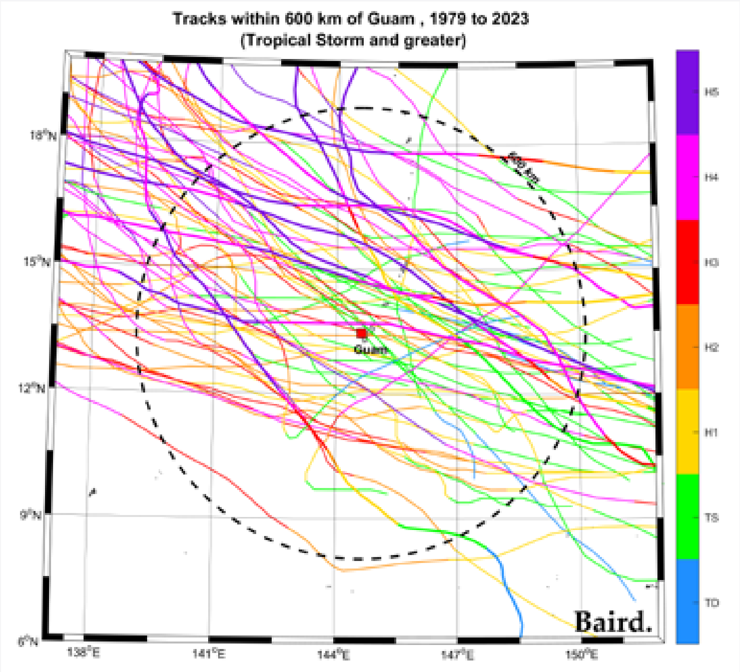
StoneID

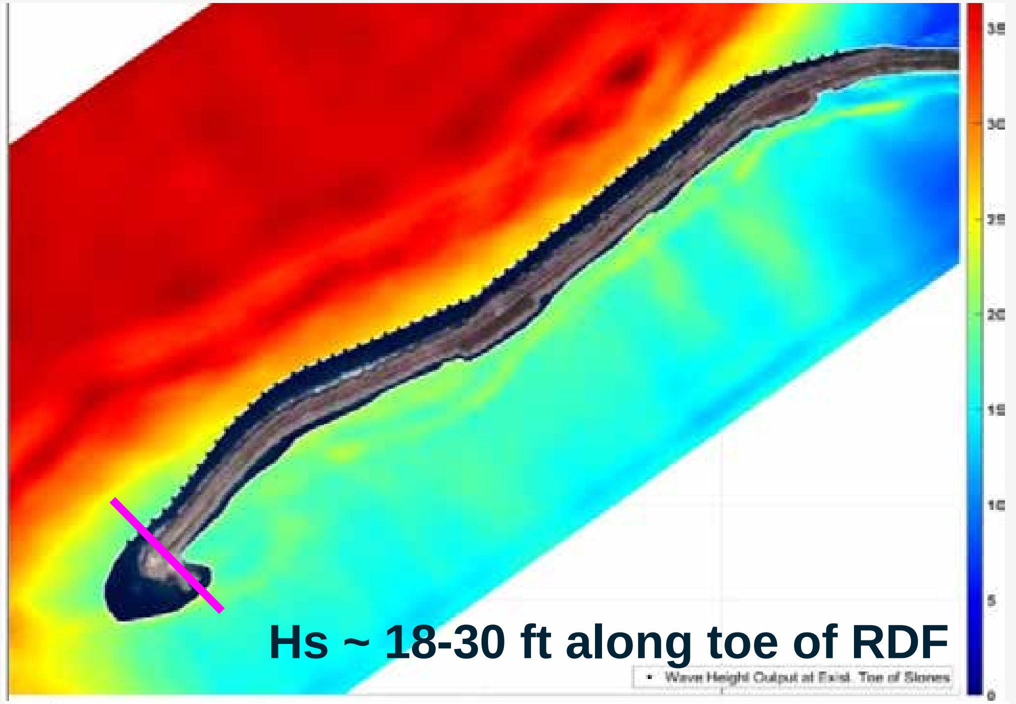


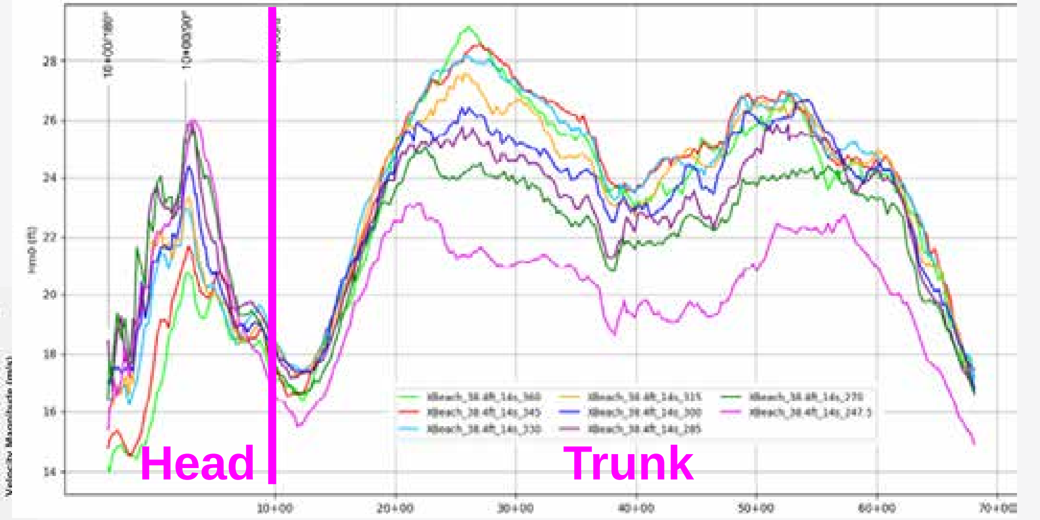
Percentile	Above Water (T)	Below Water (T)
W10	3.1	3.1
W50	9.7	8.6
W90	22.8	18.3

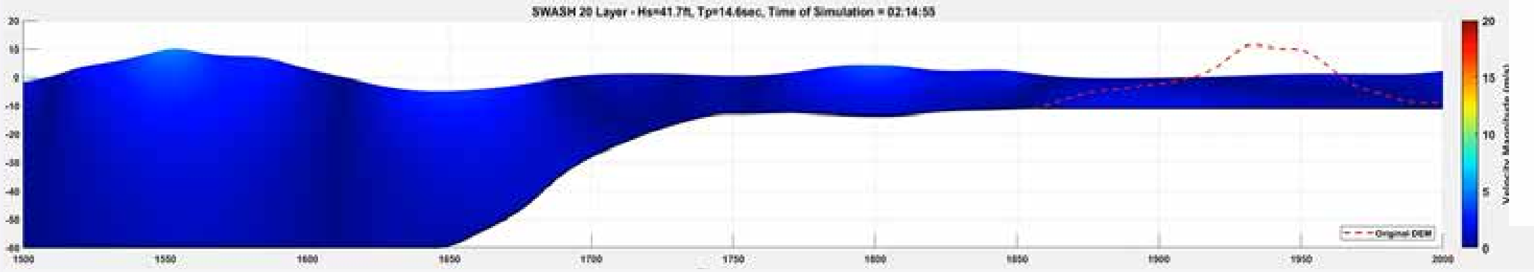
Metocean Conditions & Wave Climate

- **RFP Design Conditions**
  - 25 yr offshore Wave Height = 38.4 ft/12-14s
  - MWD = WSW-NNE
  - 100 yr HWL = +5.1 ft MLLW









Offshore

Nearshore

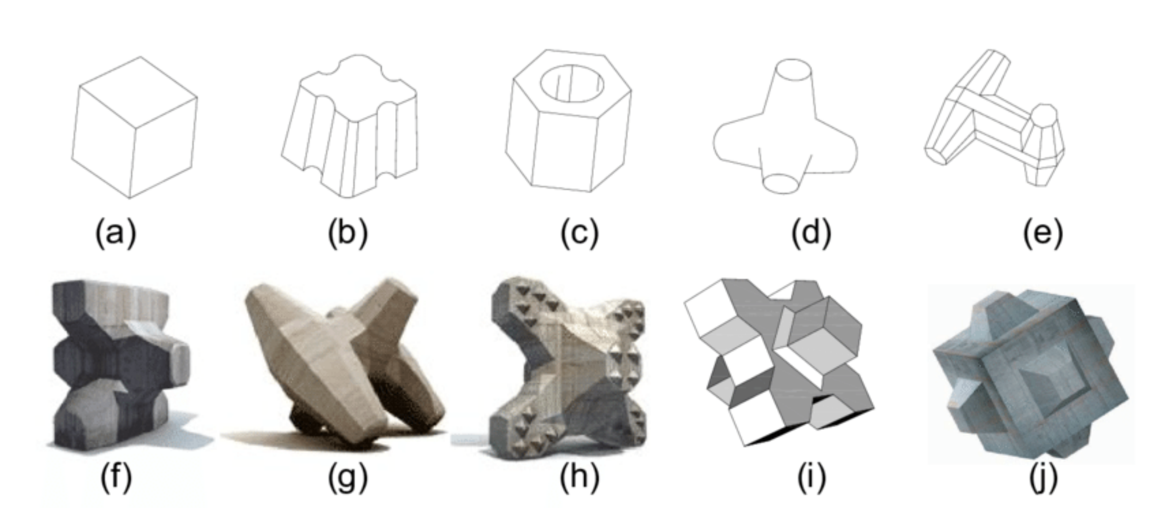
B. 1981

Alternative Design Concepts- DB Team Collaboration!

1) Quarried Stone

2) Concrete armor units (CAUs)

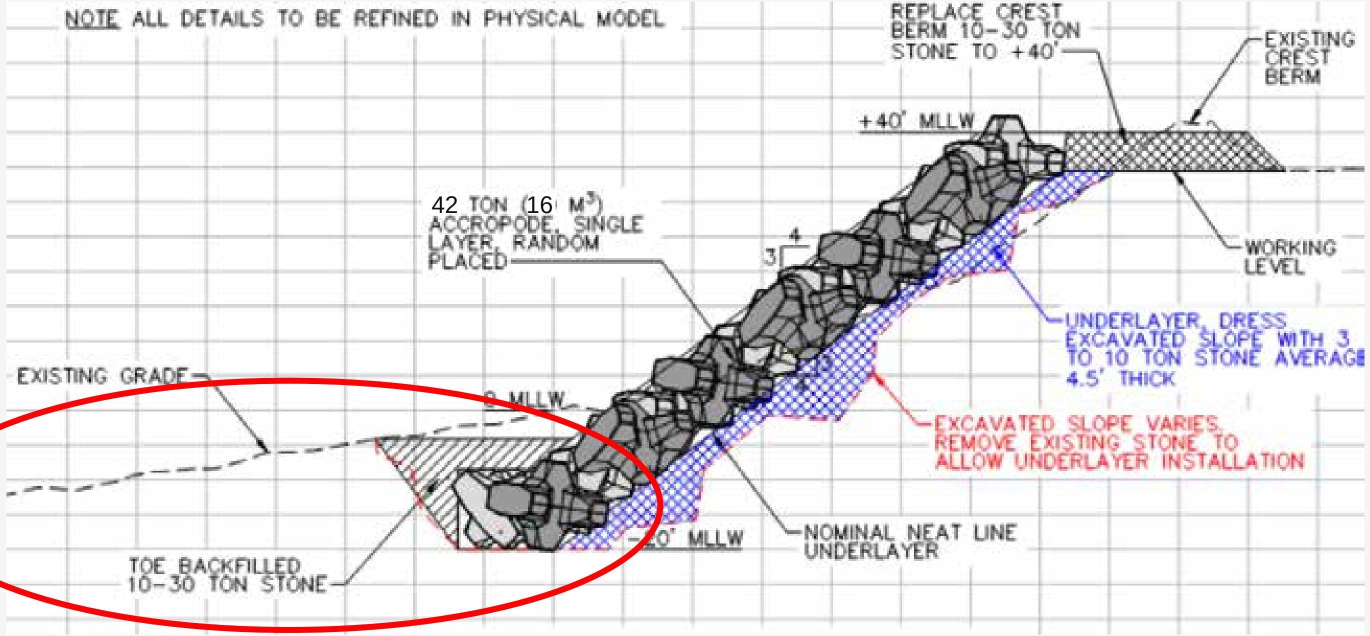
- **Slender** (Dolos, Tetrapods) - prone to rocking/breakage/failure
- **Massive** (Cubes) - inefficient
- **Bulky** (Accropodes™, Core-Loc®, X-bloc®) - best balance of hydraulic stability + structural durability



Overview of Selected Design Concept

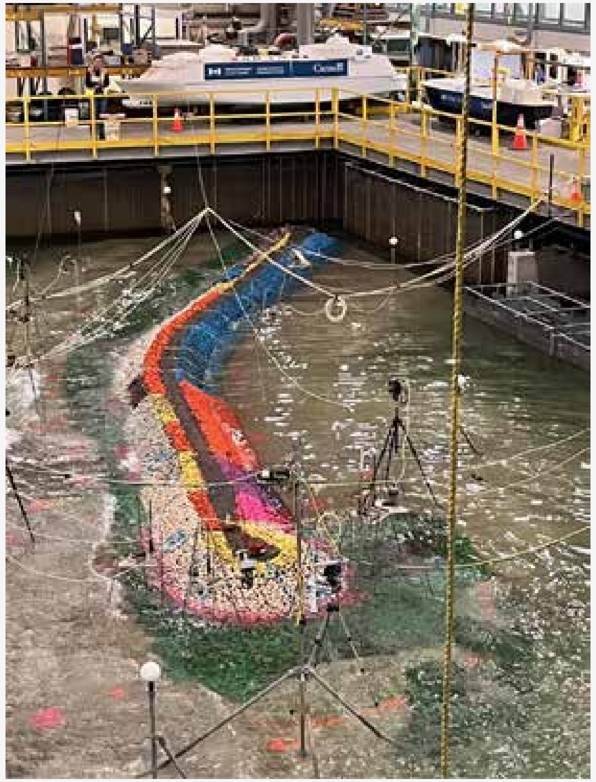
- 16 m^3 (42 T) Accropode™ units (single layer)
- Excavation/grading of existing armor stone
- Toe units embedded in trench excavated into Relic Debris Field (RDF)
- **Key Design Details:**
  - Depth of toe trench excavation into RDF
  - RDF response to extended storm exposure

} RDF is “foundation” for repair



Physical Modeling - The Design Tool!

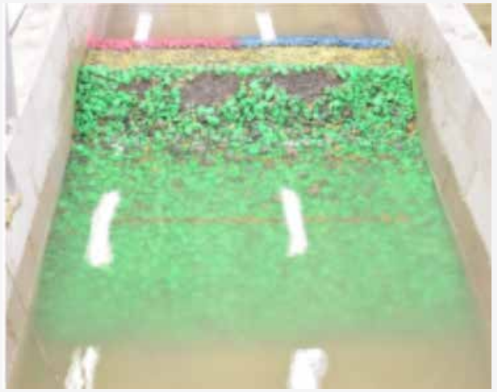
- Conducted at NRC-OCRE (Ottawa, Canada)
- Scale: 1:49.3
- Facilities:
  - 2D - 14 × 63 m Coastal Wave Basin
  - 3D - 20 × 30 m Multidirectional Wave Basin
- Key Objectives:
  - Accropode™ stability
  - Non-conventional (oversize) underlayer
  - RDF mobility
  - Toe trench depth
  - Risk of damage to partially completed work



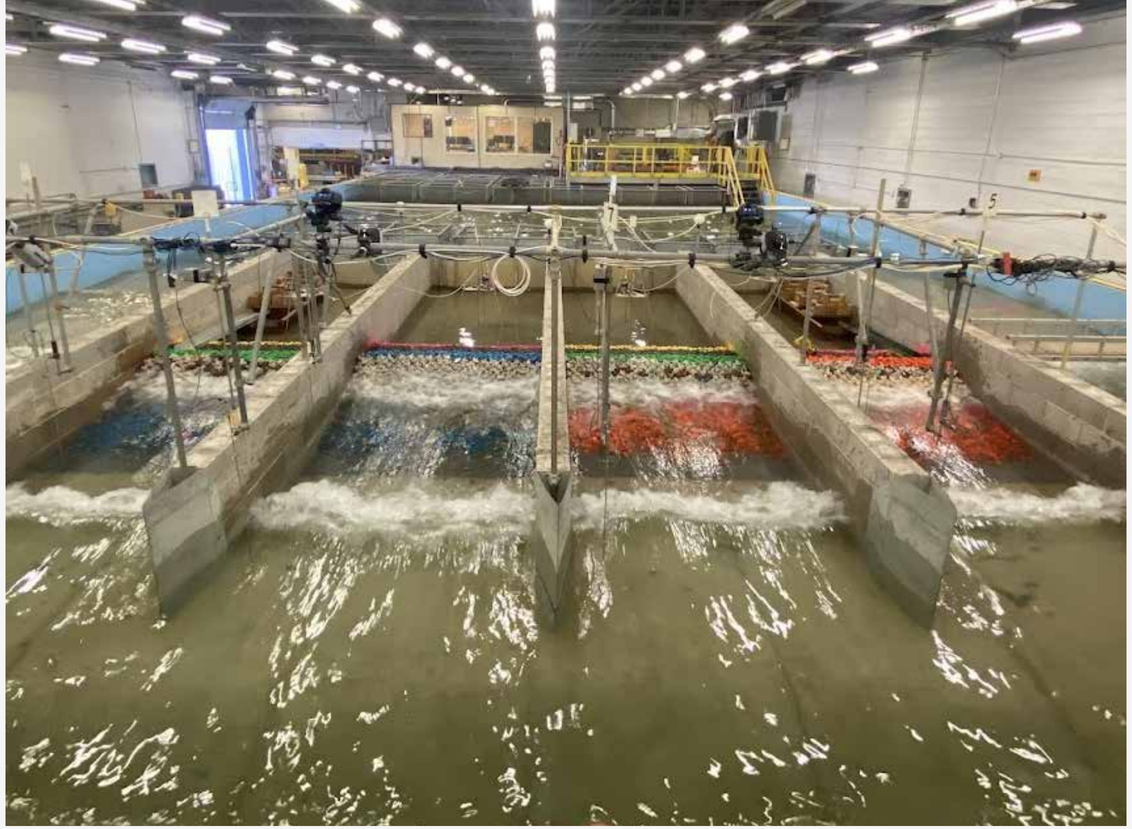
NRC-CNRC

2D Physical Model Study

- Simultaneous testing of 4 XSs
- Damage to existing structure accurately simulated



- Focus on key design parameters for repair cross-section

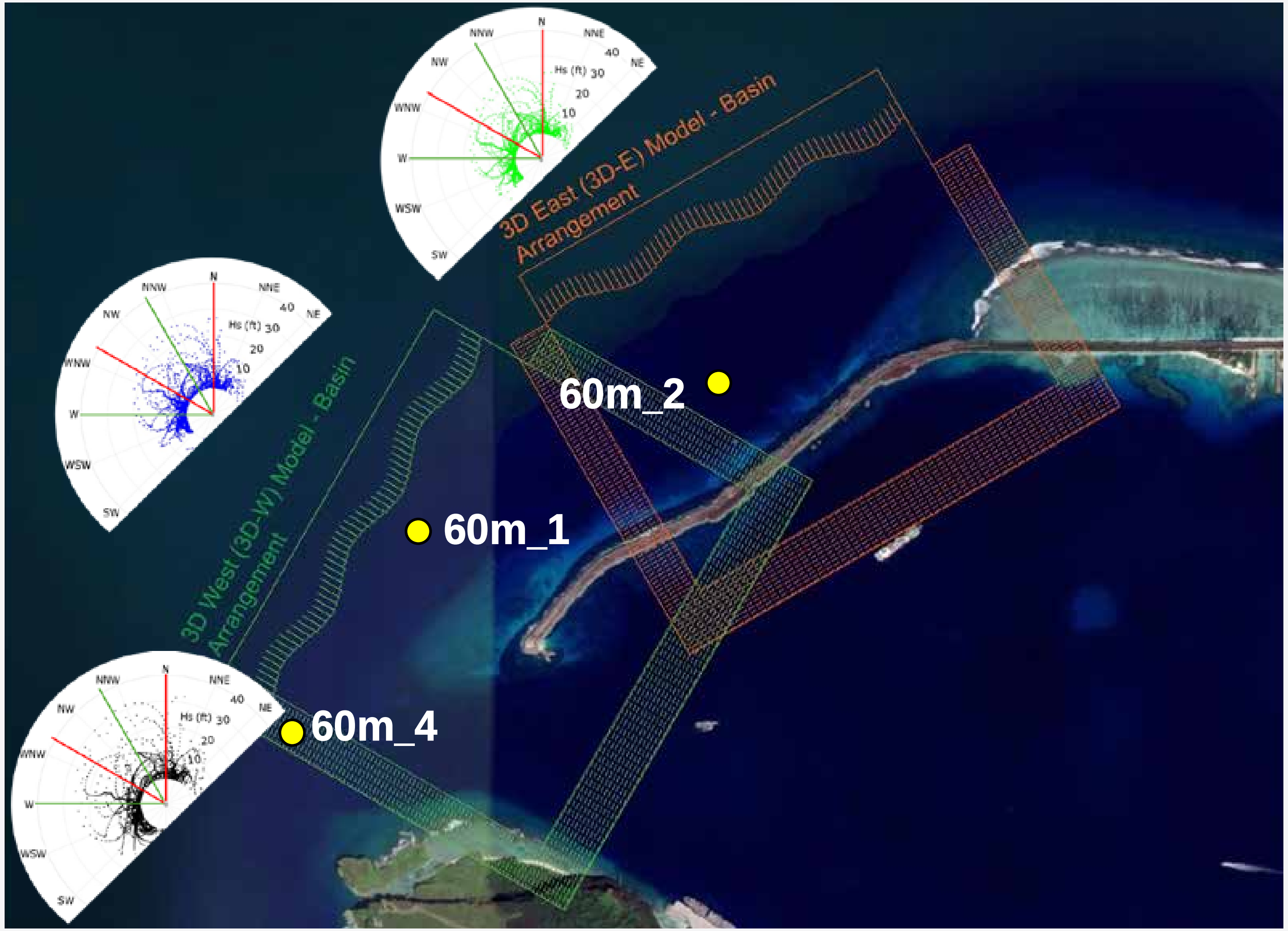


3D Physical Model Study

Two distinct 3D model studies completed to support design process:

3D-West - outer 2,700 ft (including roundhead)

3D-East - inner 3,500 ft (beyond repair termination at Luminao Reef)

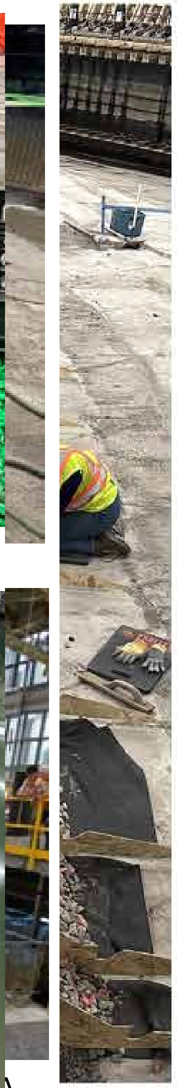


3D Model Construction

a) Accropode™ placement training along trunk

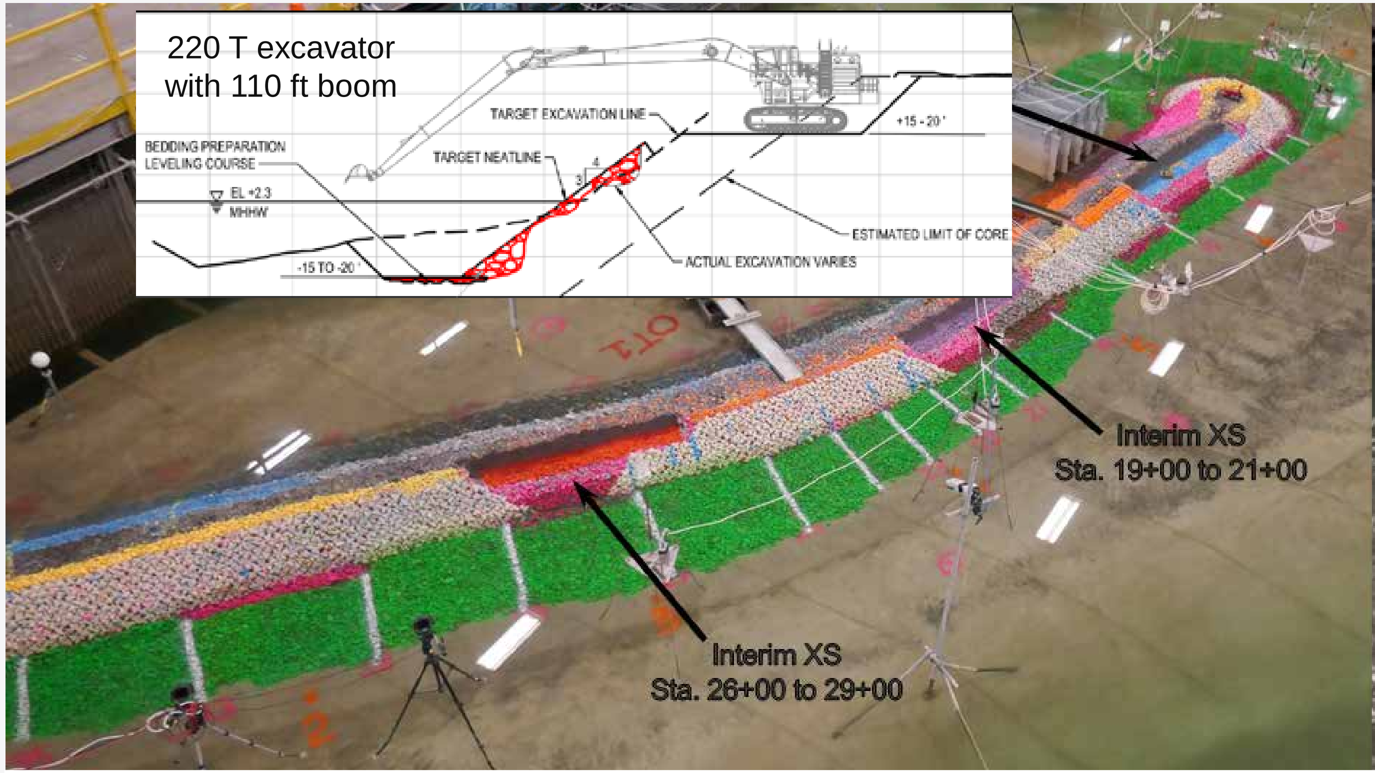
b) Accropode™ placement training along roundhead

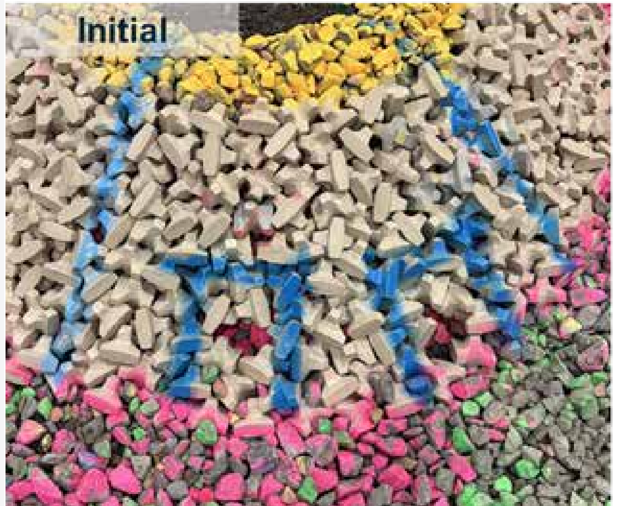
c) Completed 3D-W model (TSA)



3D-West Model - Overview

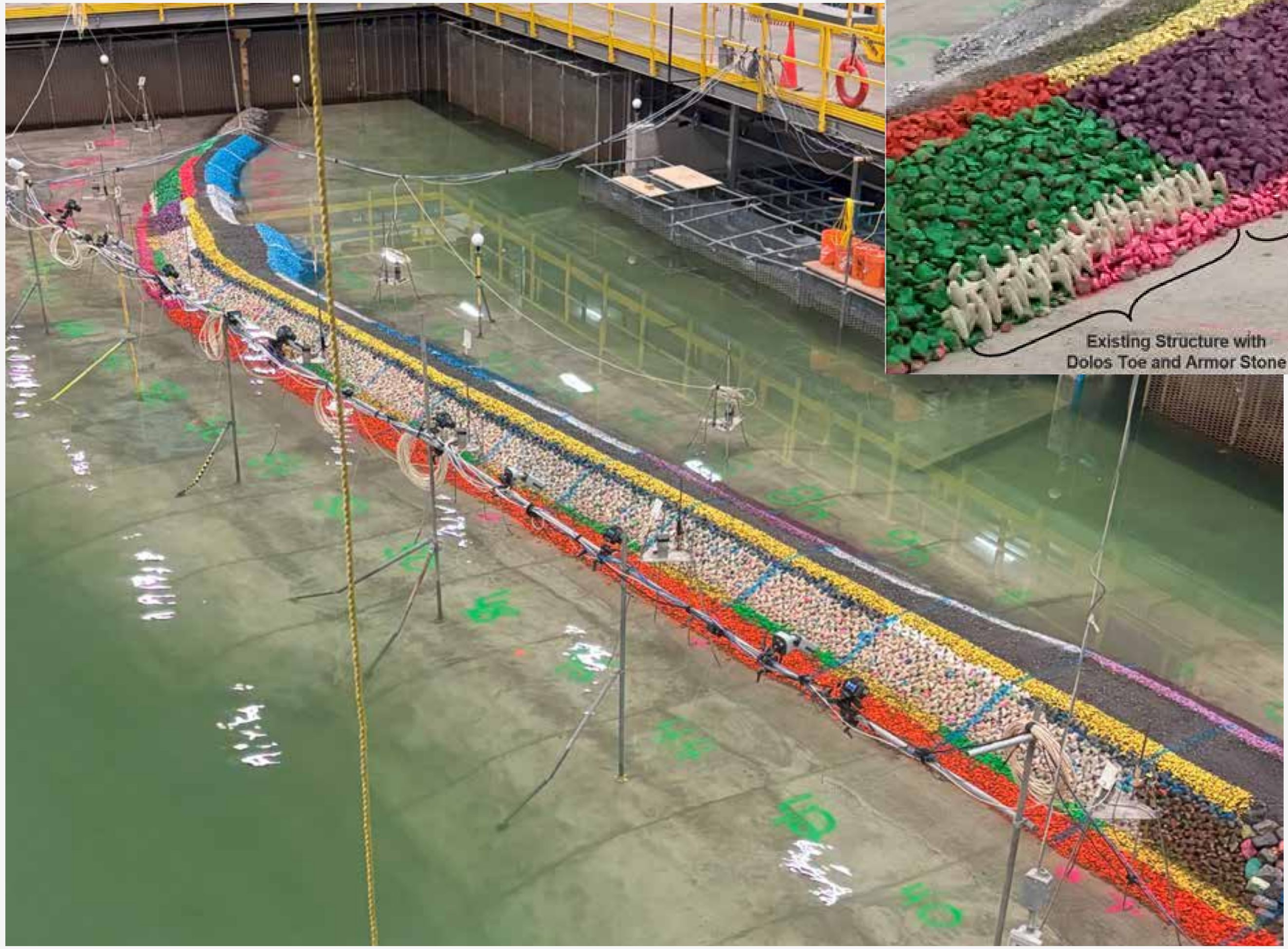
- Outer 2,700 ft, incl. roundhead
- Repair design details
  - Accropode^{TM} armor layer
  - Oversize underlayer
  - Toe trench depth + backfill
  - Overtopping + crest buttress
  - Roundhead + leeside transition
- Risk of damage to WIP
  - Excavated bench and toe
- Armor layer resilience
  - Removed Accropode^{TM} units to simulate breakage/extraction

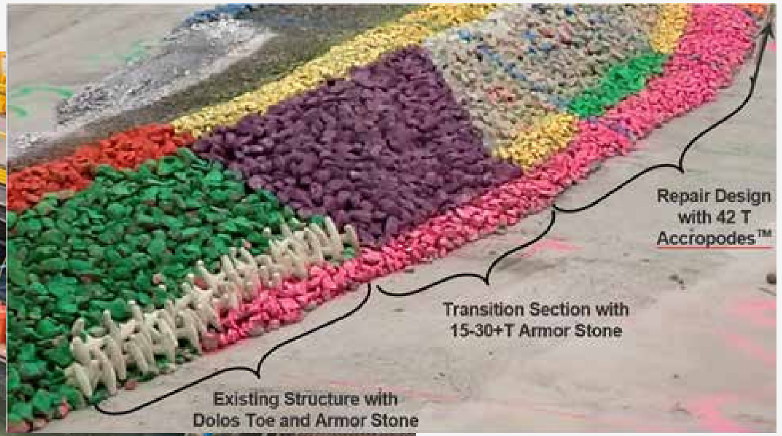


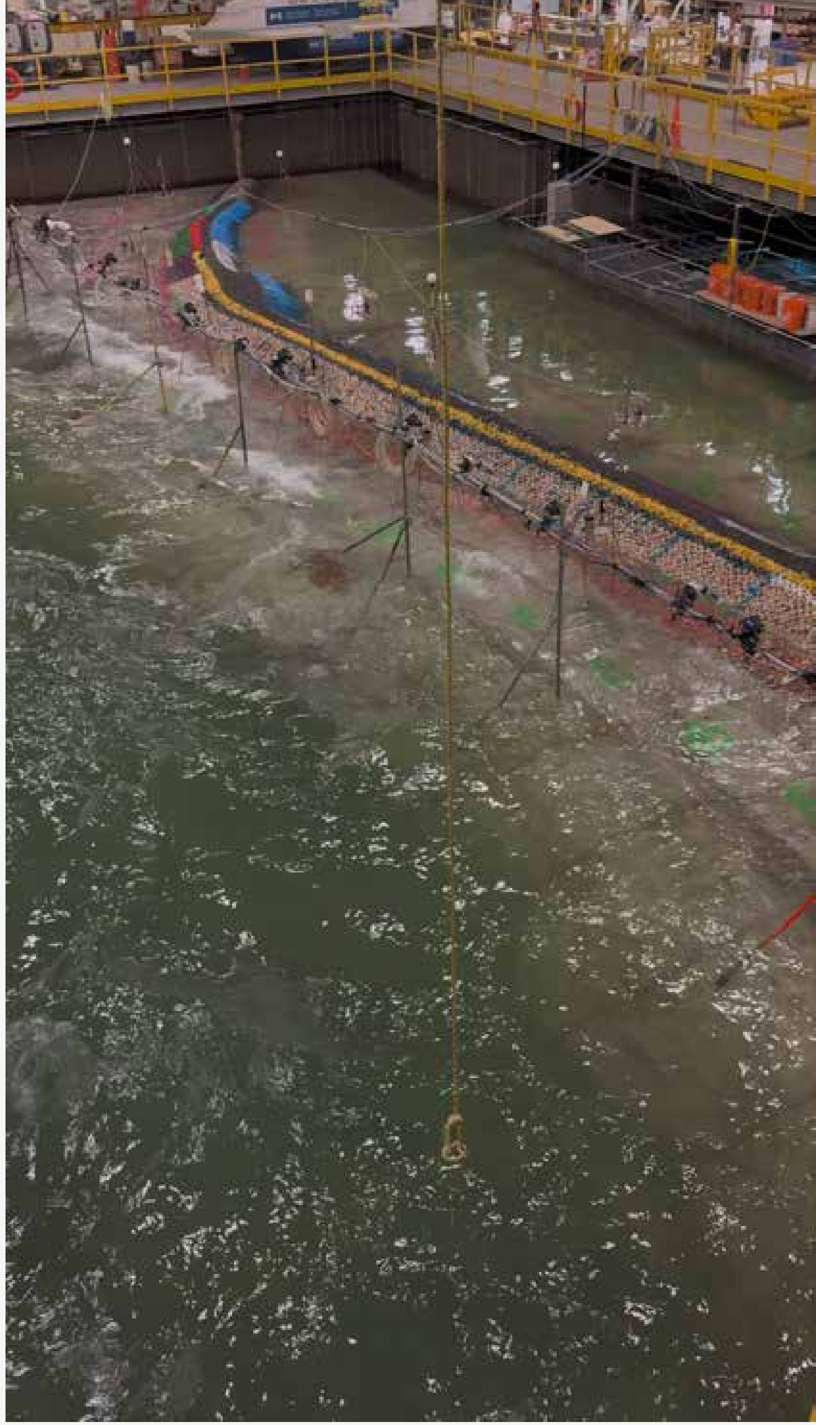


3D-East Model - Overview

- Inner 3,500 ft, incl. transition to existing structure at Luminao Reef

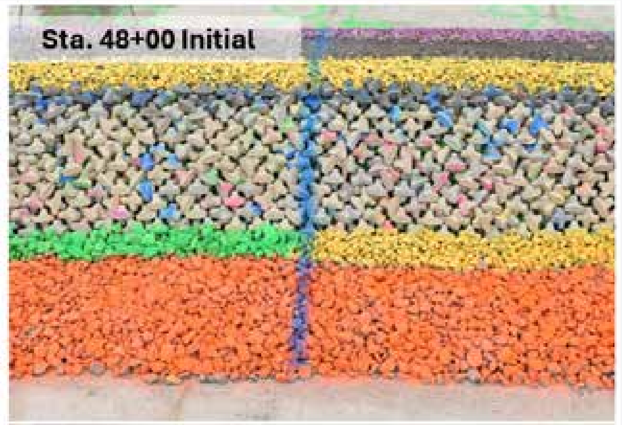


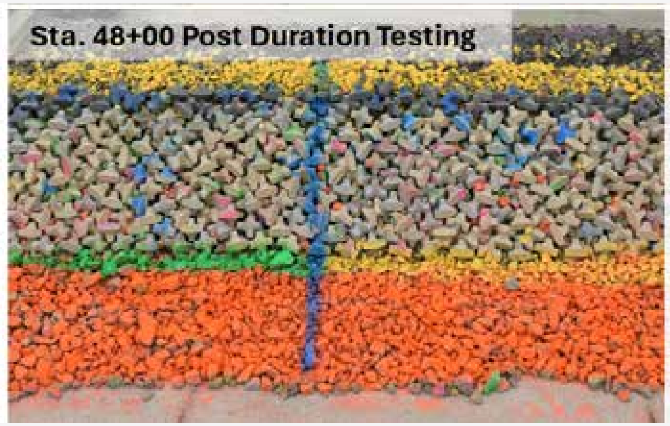


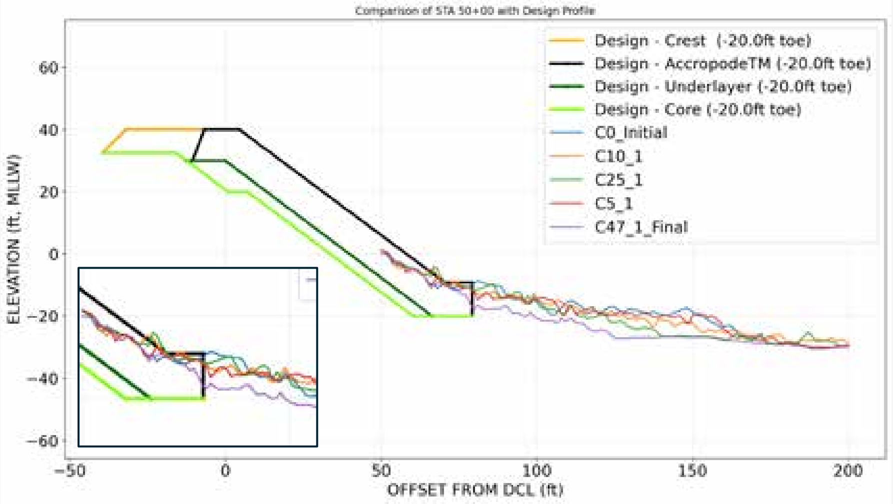


Key Model Results - Accropode™ Units

- 16 m^3 (42 T) Accropodes™ showed no sign of instability under design + overload conditions
- Armor layer provides significant design resilience
  - No extractions under extended duration of severe waves (multiple design events + overload conditions)
  - No progressive damage around artificially created gaps
- Extraction of a few toe units in some tests (3D-E model) after very long test durations (100+ yrs of storm exposure simulated)







Construction Progress

Construction Progress

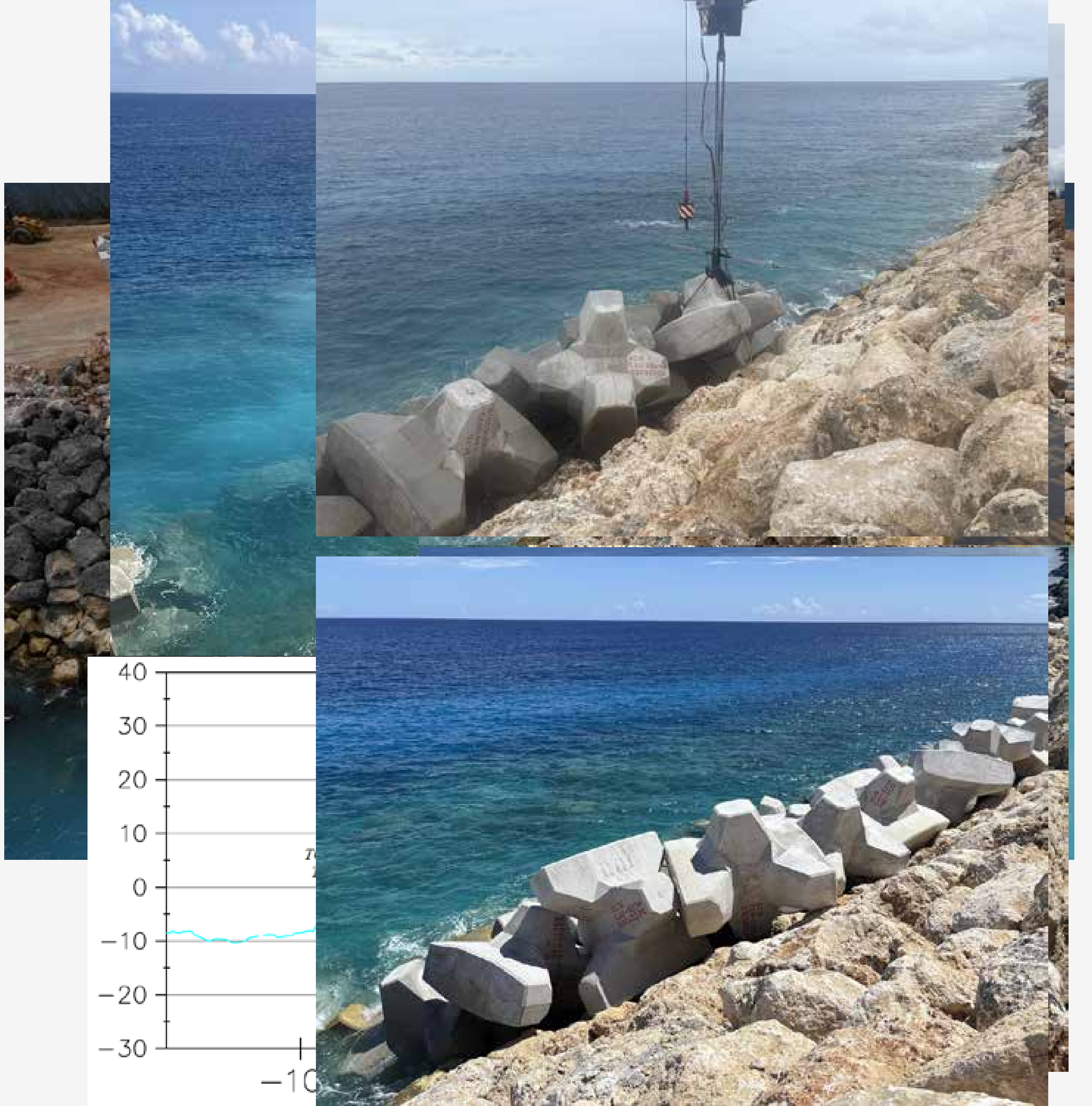
- Mob, early works + Accropode™ casting started in late 2025
- 300 ft test section advanced in early 2026
- Units Casted as of August 5th, 2026: **1,144**

Construction Sequencing

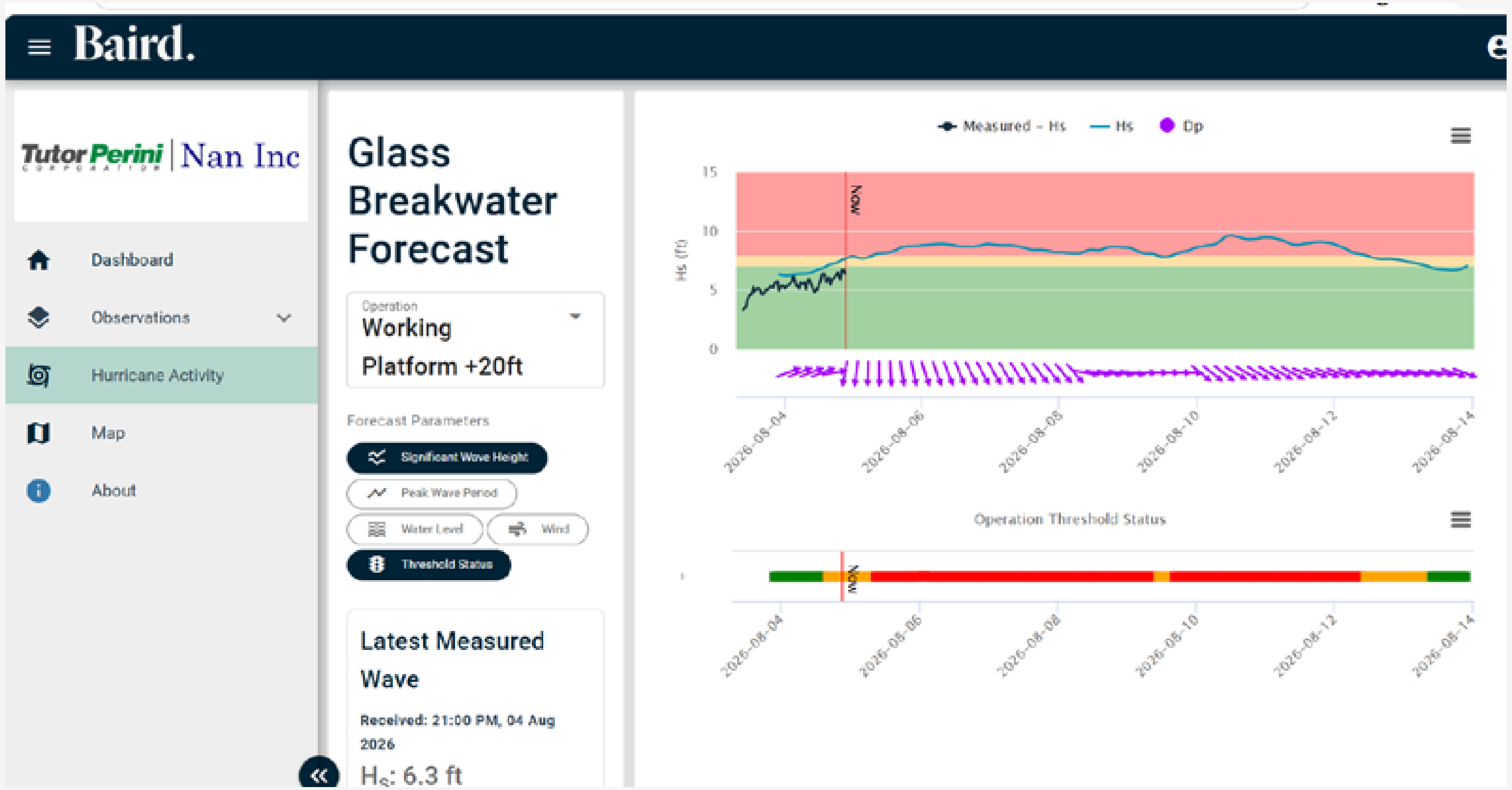
1. Construct Working Platform
   - Salvage material with excavation
2. Excavate Toe Trench & Underlayer to Platform

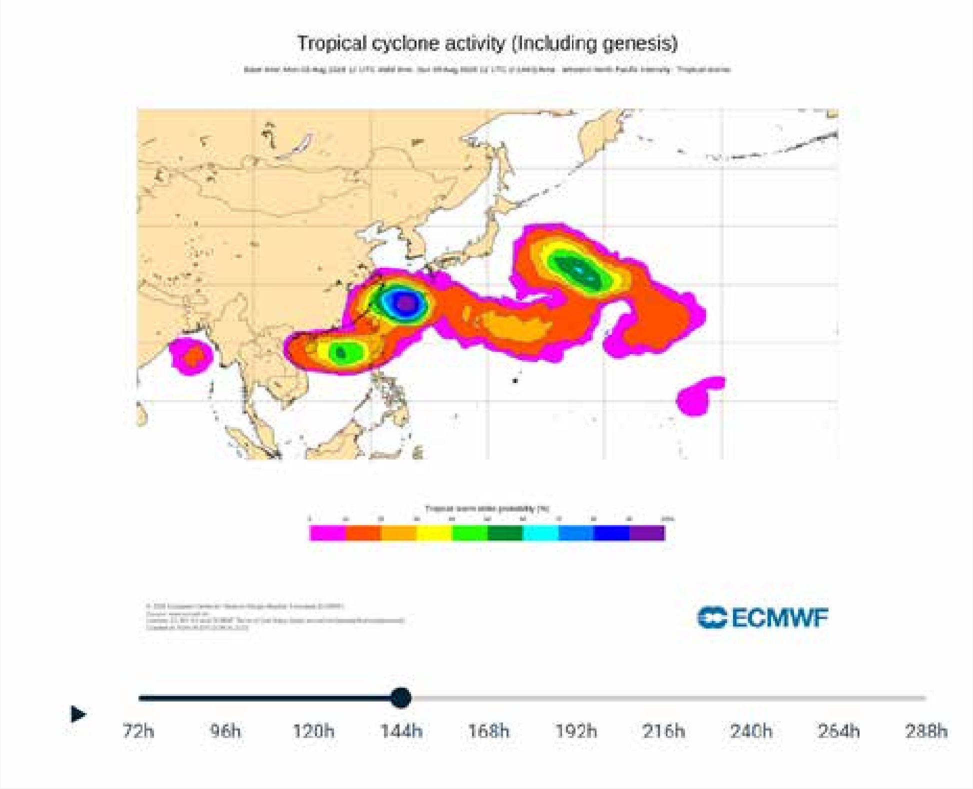
3. Backfill Working Platform & Complete Underlayer

4. Place Accropode™ units



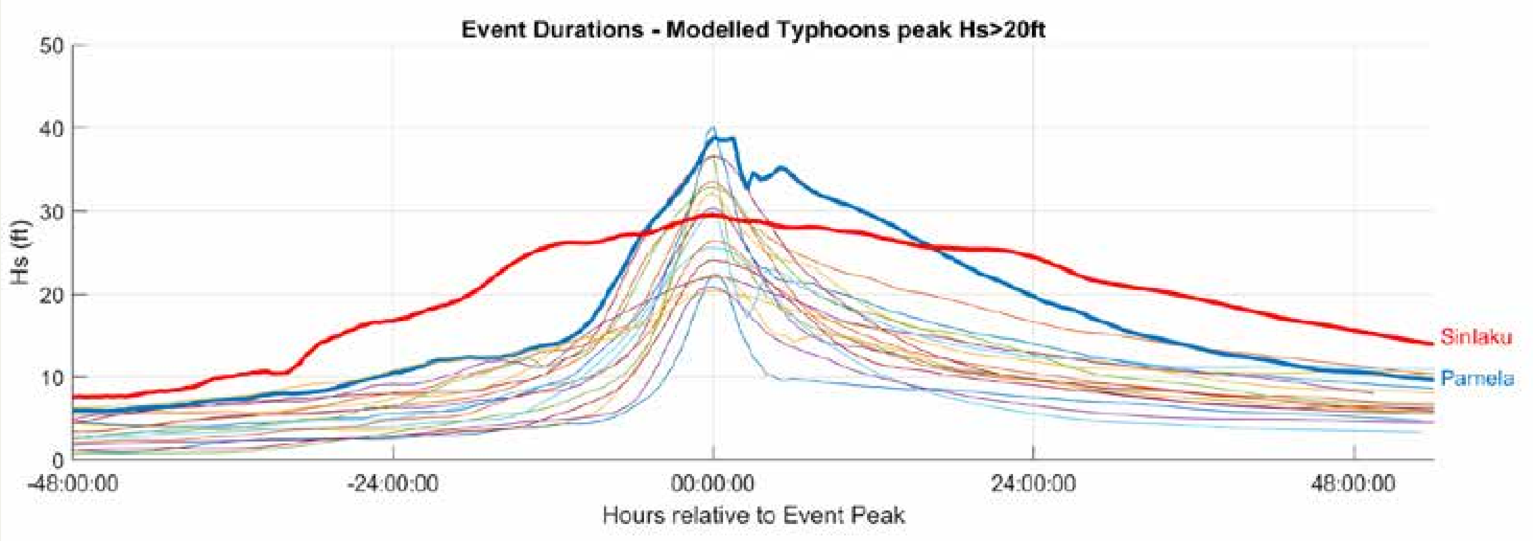
Construction Progress- Operational Conditions Forecast

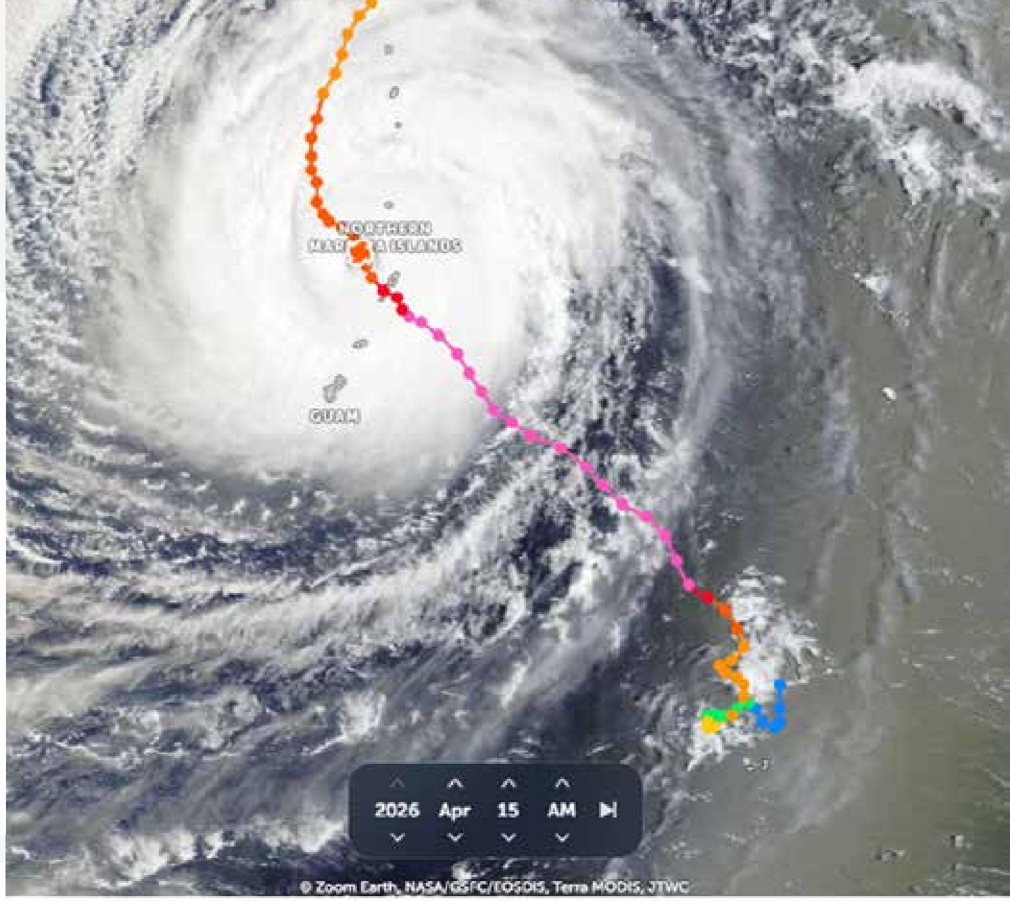




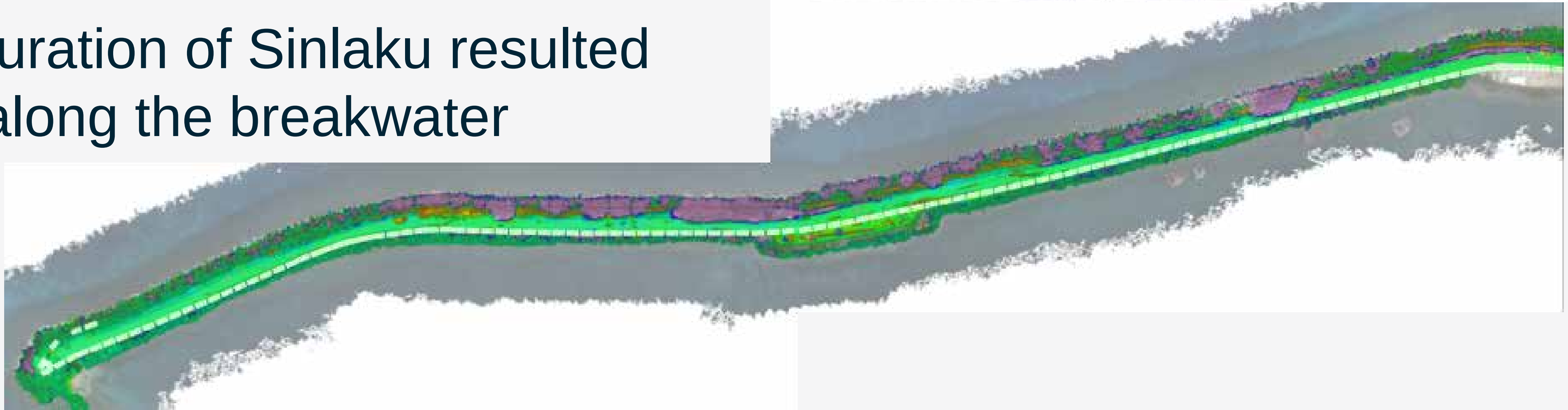
Super Typhoons Sinlaku and Bavi

Super Typhoon Sinlaku





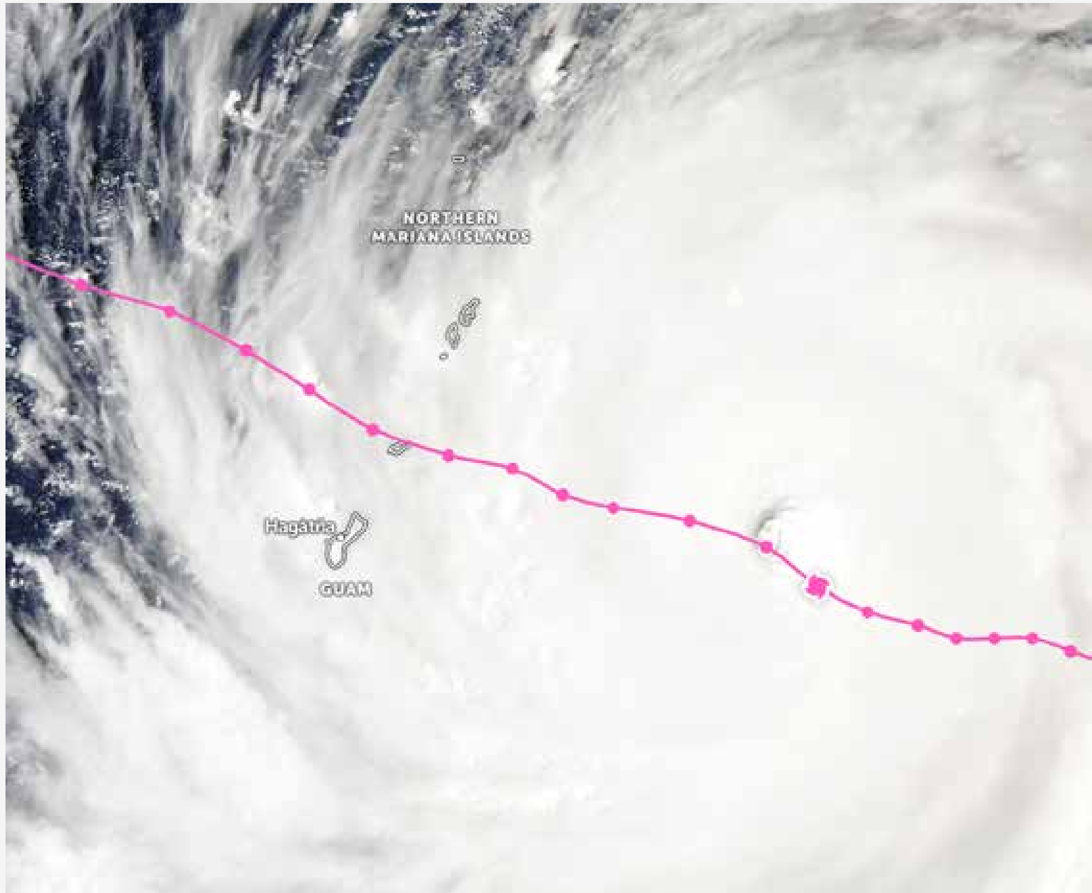
- Extended Duration of Sinlaku resulted in damage along the breakwater

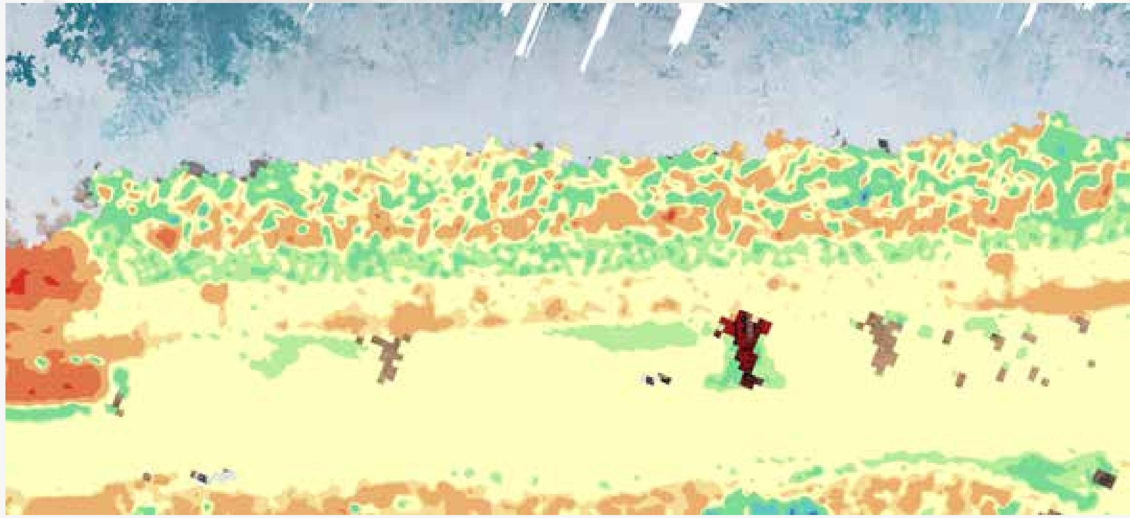


Emergency Response to Super Typhoon Sinlaku

Super Typhoon Bavi

- Sinlaku related repairs completed
- Accropode™ Placement Completed for ~400ft
- Typhoon Bavi July 5-6th, 2026
- Placed units remained intact and stable
- Fewer Emergency Repairs required compared to Sinlaku





Path Ahead

- Complete Emergency Repairs
  - Use imported stone from Korea to replace volume loss due to Sinlaku and Bavi
- Progress with the Permanent Repair Design with Accropode™

Questions?