Resolute Marine Energy

Clean Energy From Ocean Waves

Yakutat Wave Energy Project

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Presentation Outline

- Yakutat's Problem
- Yakutat Project Background
- Wave Energy Resource and Challenges
- Advantages of RME's SurgeWEC™ Technology
- RME's R&D on SurgeWEC™ designs
  - June 2010 tank tests at Alden Labs in Holden, MA
  - June 2011 tank tests at BOEM (Ohmsett, NJ)
  - Dec. 2011 ocean tests at Nags Head, NC
  - Dec. 2012 ocean tests at Duck, NC
- Details of the Yakutat Wave Power Project

Much of RME's R&D has been supported by the US Department of Energy Water Power Program via SBIR Phase 1 and Phase 2 awards. THANK YOU!

Yakutat's Problem

- Community of 650 depends upon diesel generators for electricity
- Diesel fuel shipped by barge from Anacortes, WA (>1,100 miles)
- Fuel prices have been in the range of $5.00 - $8.00/gal.
- Consumes ≈ 420,000 gallons of diesel fuel/year
- $2.0 - $3.0 million/year spent on fuel
- Cost of Energy to Yakutat Power $0.55 - $0.60/kWh
- Viability of fish processing plant threatened
- Yakutat population declining
- Many AK rural communities have same problem as Yakutat

Yakutat Project Background

December 2009 – EPRI releases Yakutat wave energy feasibility study

- Funded by DOE, State of Alaska and City & Borough of Yakutat ("CBY")

Significant Findings

- Excellent deep & shallow water wave resource
- Gently sloping seabed (long distance to deep water)
- Installation/maintenance costs likely significant (need to be minimized)
- A shallow-water (near-shore) WEC technology likely a "best fit"

October 2011 - RME meets Yakutat Power at the Alaska Rural Energy Conference in Juneau and discussions begin

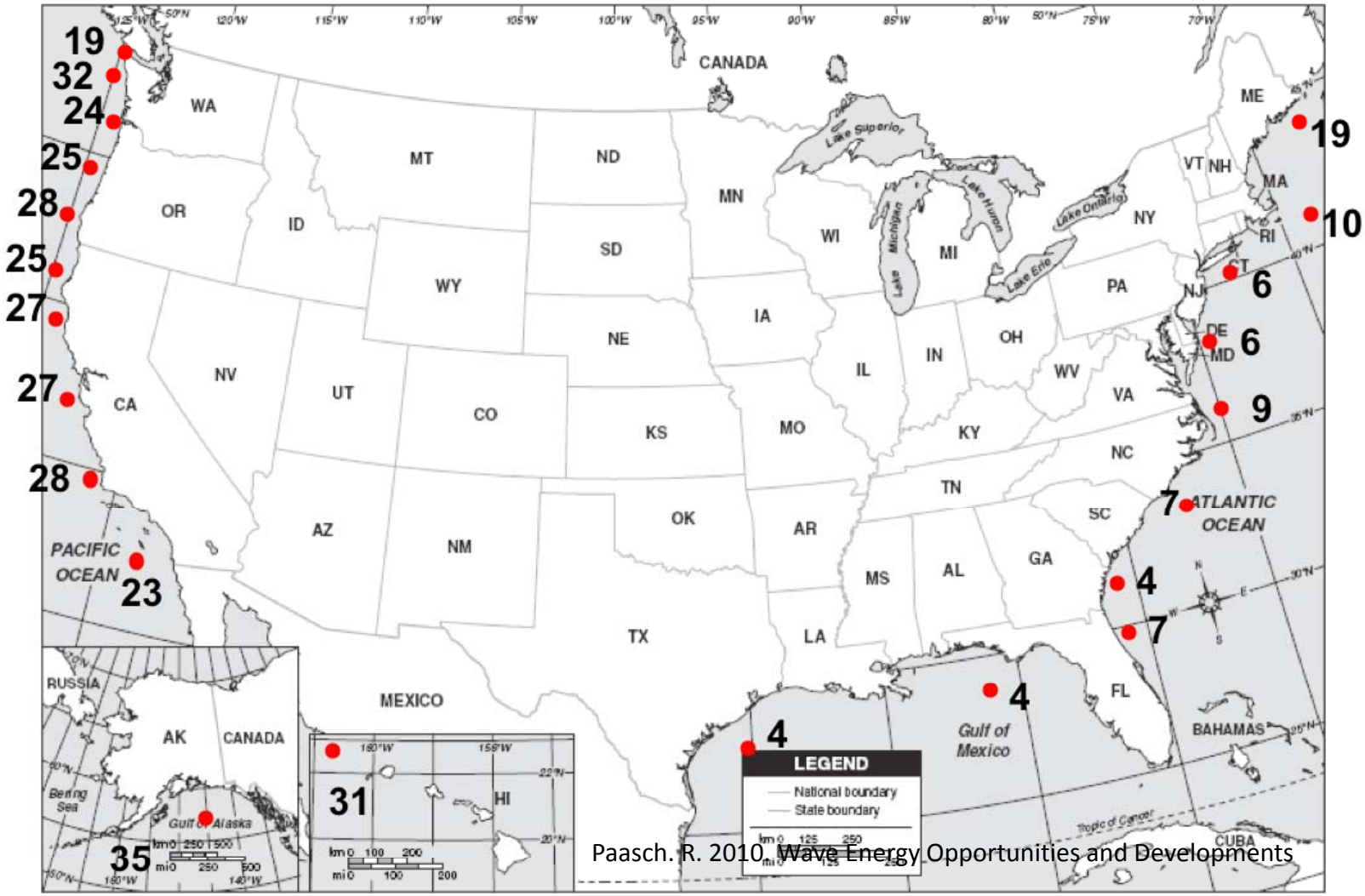
February 2012 – RME visits Yakutat to begin preliminary surveys

June 2012 – RME files Preliminary Permit application with FERC

January 2013 – FERC approves Preliminary Permit application

April 2013 – RME & CBY commence meetings with federal & state regulators in Juneau

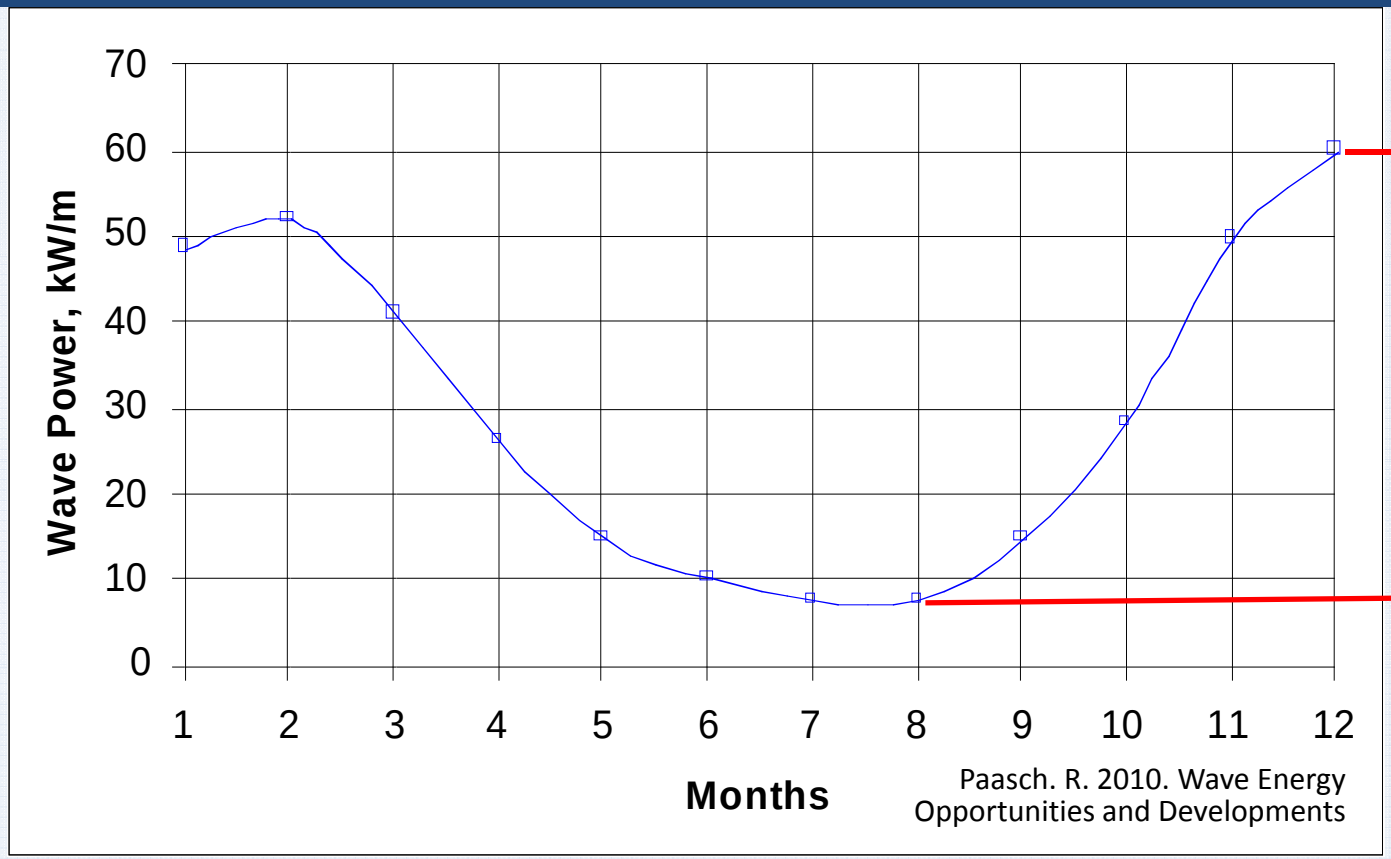
US Wave Energy Resource – Alaska the US leader by far



Paasch. R. 2010. Wave Energy Opportunities and Developments

NOTE: Figures denote annual average energy flux in kilowatts/meter of wave front

Seasonal variability of wave energy presents challenges



An eight-fold seasonal difference! What is your design condition?

Wave data From National Data Buoy Center, Power estimated from five buoys off the Oregon coast over past 10 years)

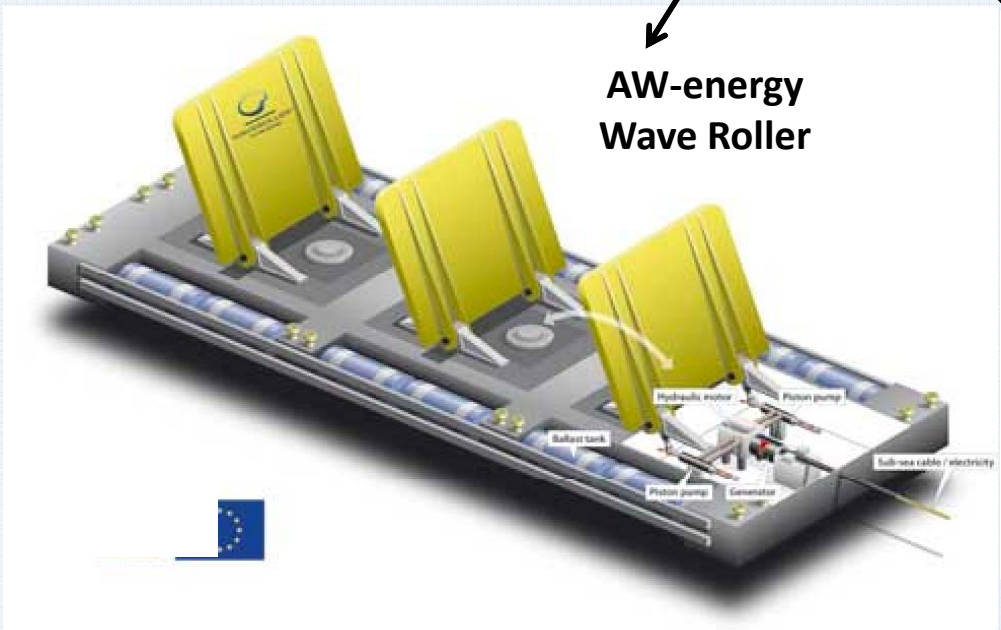
NOTE: Other design challenges include survivability, reliability and tidal range accommodation

Advantages of the SurgeWEC™ Technology

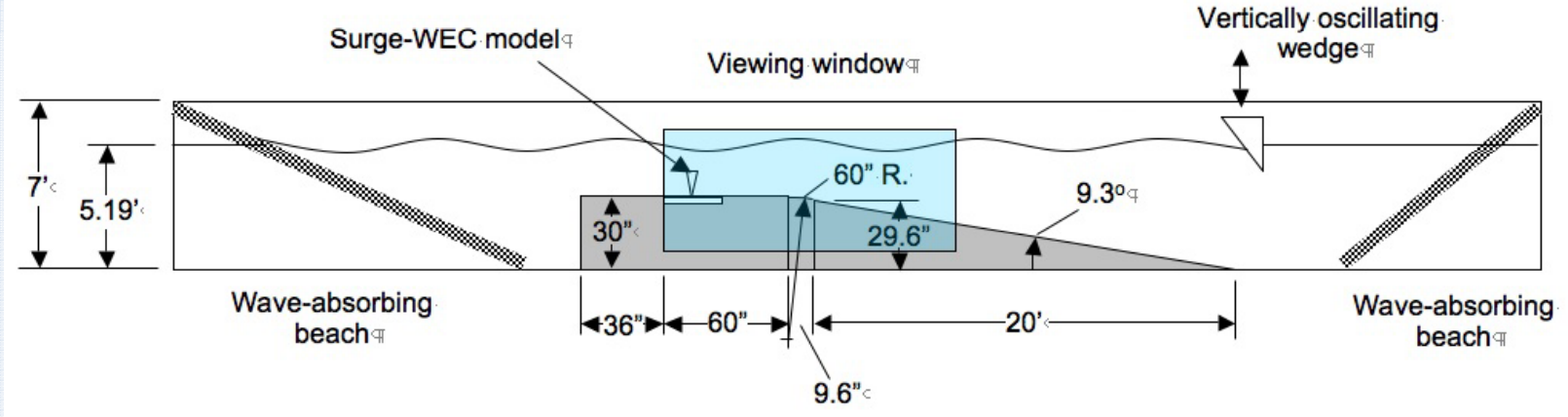
- Deployed near shore (lower energy transmission costs)
- Excellent energy conversion efficiency (30-40% compared to 10-20%)
- No view shed impact (flaps remain underwater)
- Benign to marine life (no entanglement risk, low flap velocity)
- Relatively immune to extreme loads caused by large waves (flap can be locked in horizontal position during storms)

Other flap-type WECs

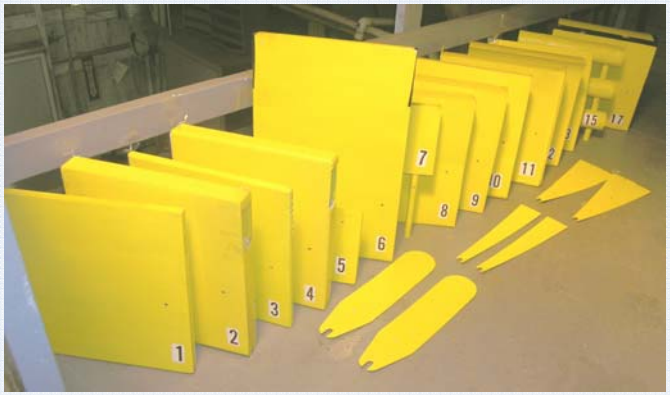
AW-energy Wave Roller

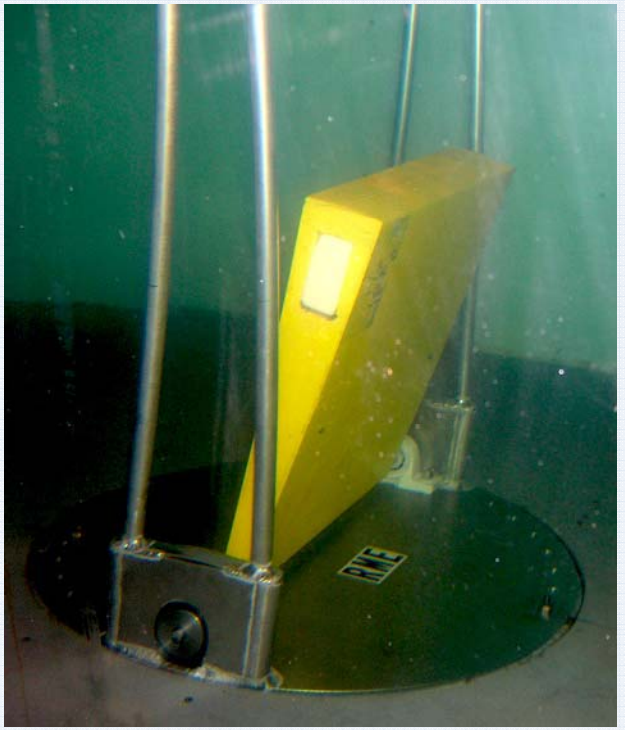


June 2010 tank tests at Alden Labs in Holden, MA



This SBIR Phase 1 laboratory-scale project examined of the role of paddle size and section shape on power generation.
Tests of 17 shapes revealed the importance of optimum damping and paddle righting moments on power extraction.



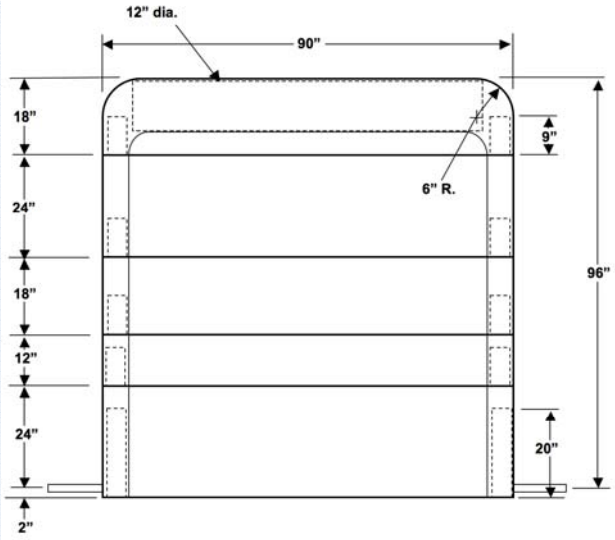


June 2011 prototype tests at BOEM Ohmsett in Leonardo, NJ

A 203 m long by 20 m wide by 3.4 m deep outdoor tank with 2.6 million gallons seawater able to generate regular waves and sea spectra up to 1 m.

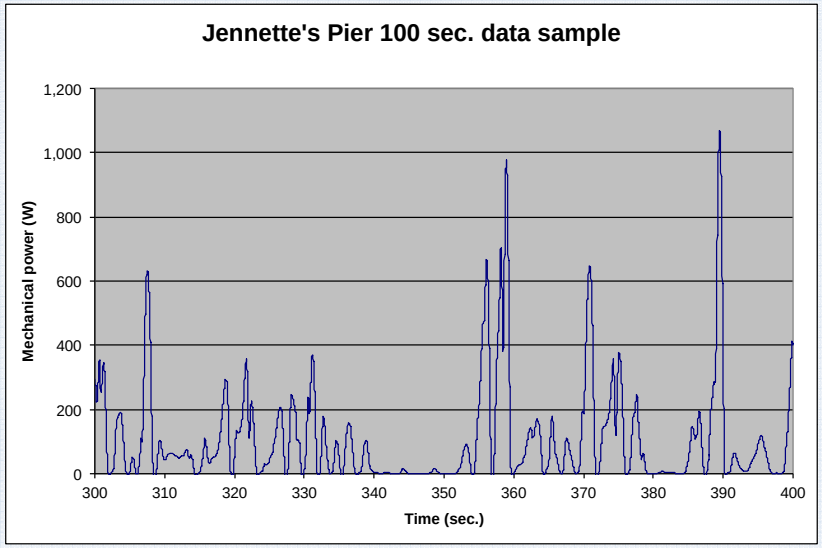
These experiments focused on the effects of paddle height vs. depth and the role of paddle buoyancy on performance at a water depth 2 m above the paddle hinge.

Paddle heights from 1.1 to 2.2 m were tested. An important goal was correlating these findings with a parallel numerical analysis focus.

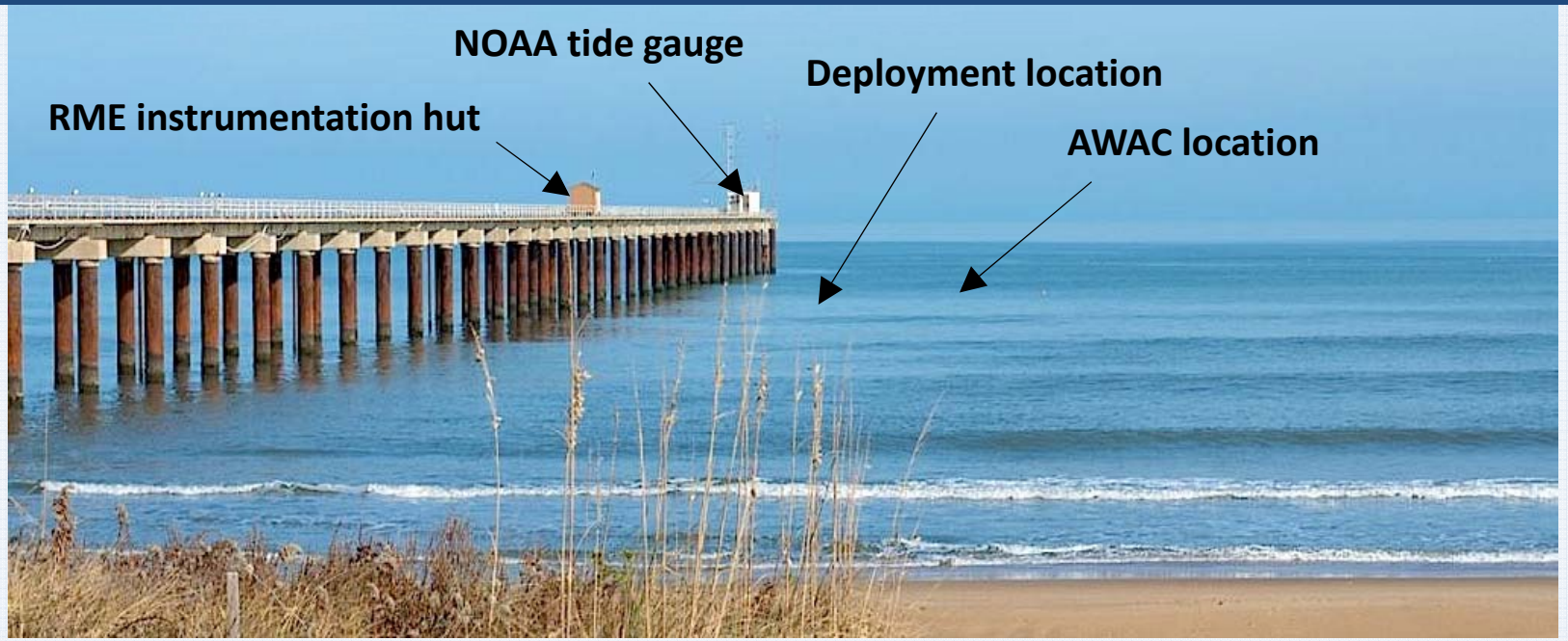


Dec. 2011 ocean tests of a 3.8 m^2 prototype at Nags Head, NC

Hosted by the UNC Coastal Studies Institute, 305 m long Jennette's Pier provided a convenient venue for the initial sea trials of a 2.3 m wide by 1.7 m tall paddle. Deployment depth was 7.5 m at the end of the pier. (h/d = 0.23)



December 2012 – January 2013 test program @US Army Corps of Engineers Field Research Facility - Duck, NC

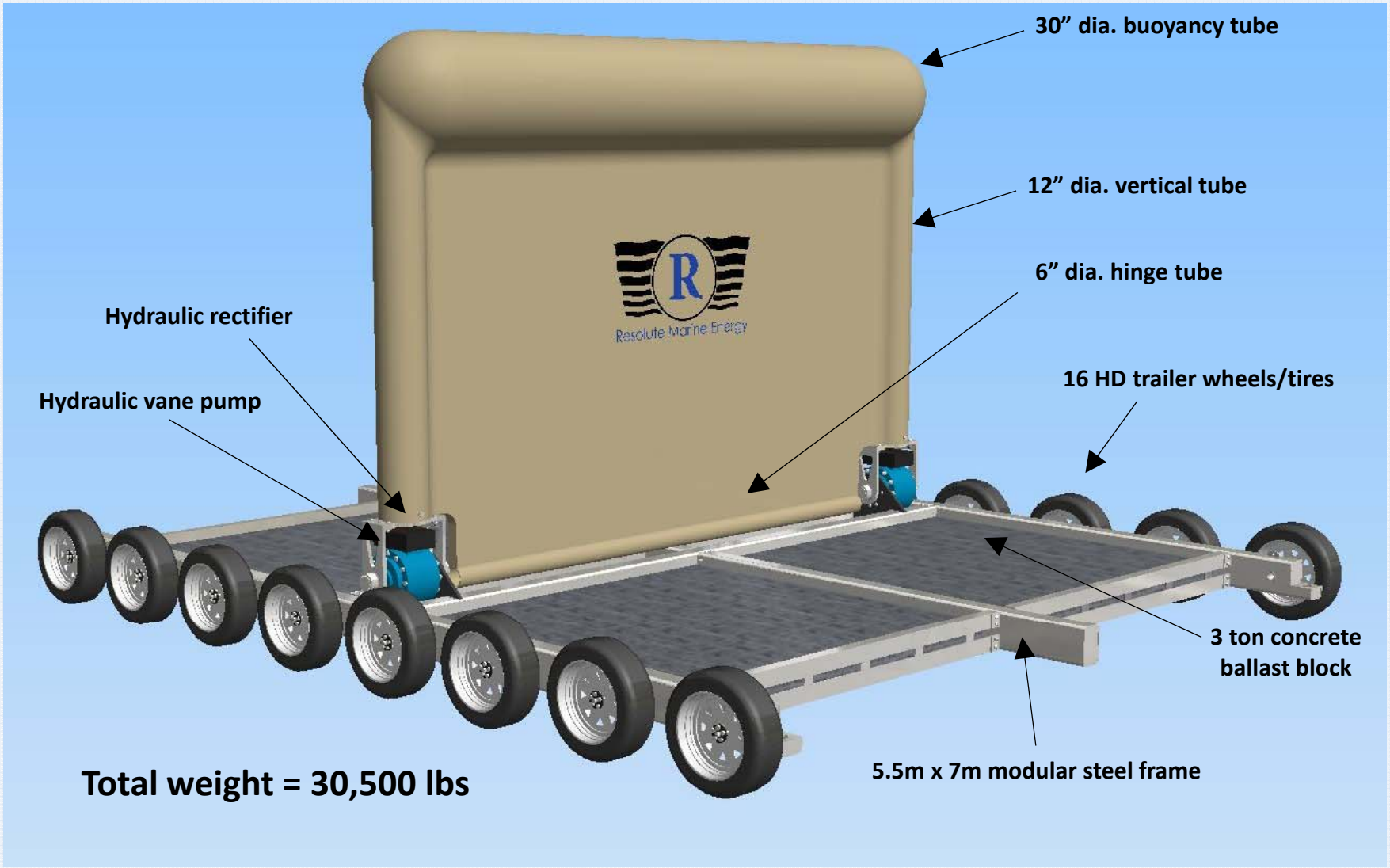


560 m (1840 ft) Pier

LARC-5 amphibious vehicle

CRAB

SurgeWEC™ 17.5 m^2 OWSC prototype tested at Duck



SurgeWECs can be quickly assembled & deployed from shore without the need for special-purpose vessels

WEC/pipeline installations completed quickly & safely

No expensive barges or cranes required

Simplified maintenance (all done onshore)

Duck Shore-Based Equipment

Accumulator Pack

Six 10 gallon 3000 psi accumulators
Inlet and outlet flow meters
Motorized needle valve shunt

Motor/Generator

SauerDanfoss variable displacement
Marathon 1200 rpm 220V-3P generator

National Instruments DAQ/Labview

- **8 hydraulic pressure sensors**
- **2 hydraulic flow meters**
- **Wave sensor array (4 UW pressure)**
- **Acoustic wave probe**
- **Paddle angle**
- **RPM & electrical output**

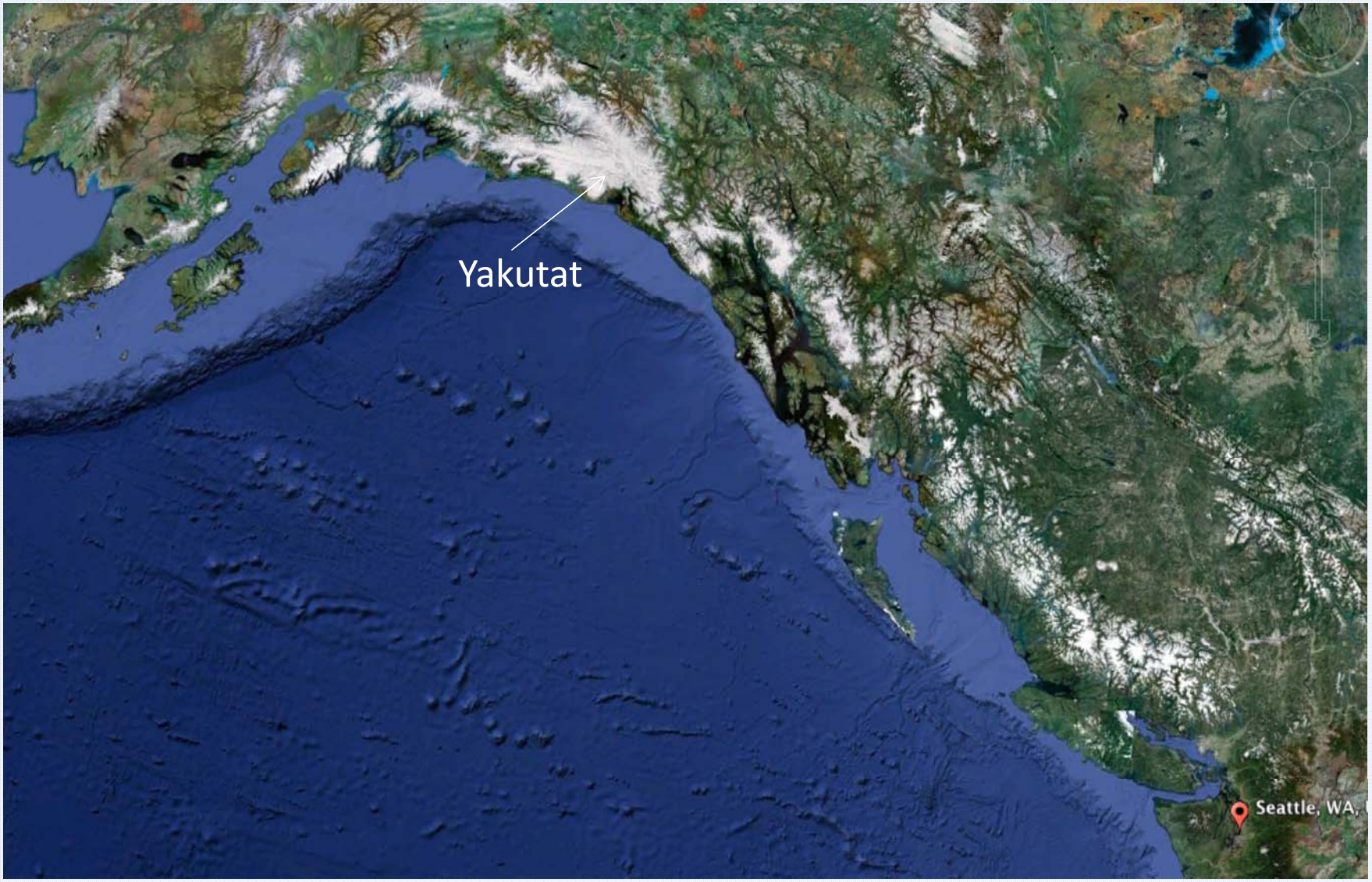
Highlights of SurgeWEC™ Ocean Trials at USACE Duck

- 30% conversion efficiencies achieved
- Successful demonstration of simplified deployment method
- Hydraulic accumulation system performed as expected
  - Spun generator at a constant speed
- Clarified effects of damping control on extraction efficiency
- Sensors provided accurate information about forces
- Good agreement with our numerical simulations
  - ≈ 80% accuracy

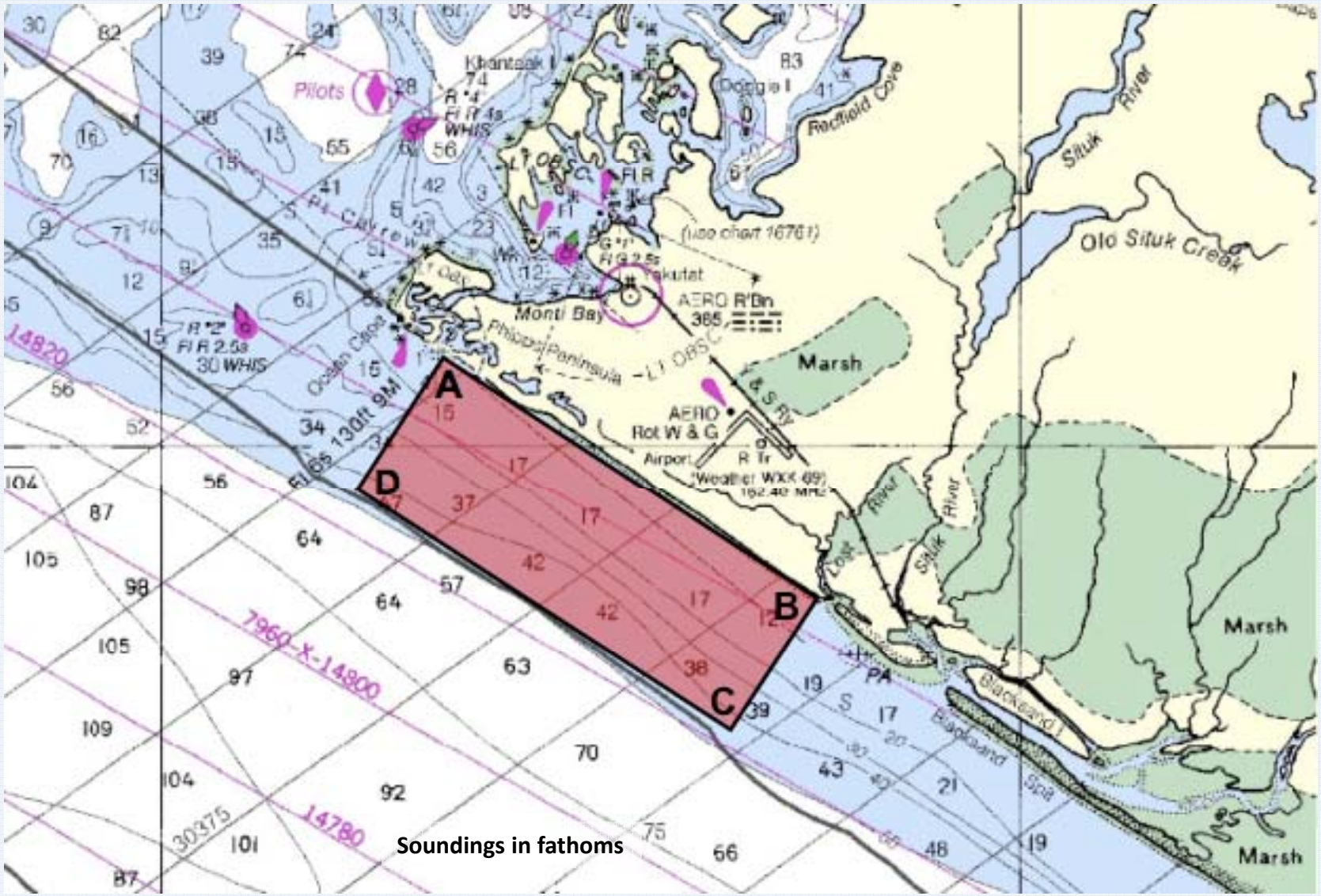
SurgeWEC™ has now logged over 1,200 hours of ocean testing and ≈ 1.5 million flap oscillations

Details of the Yakutat Wave Power Project

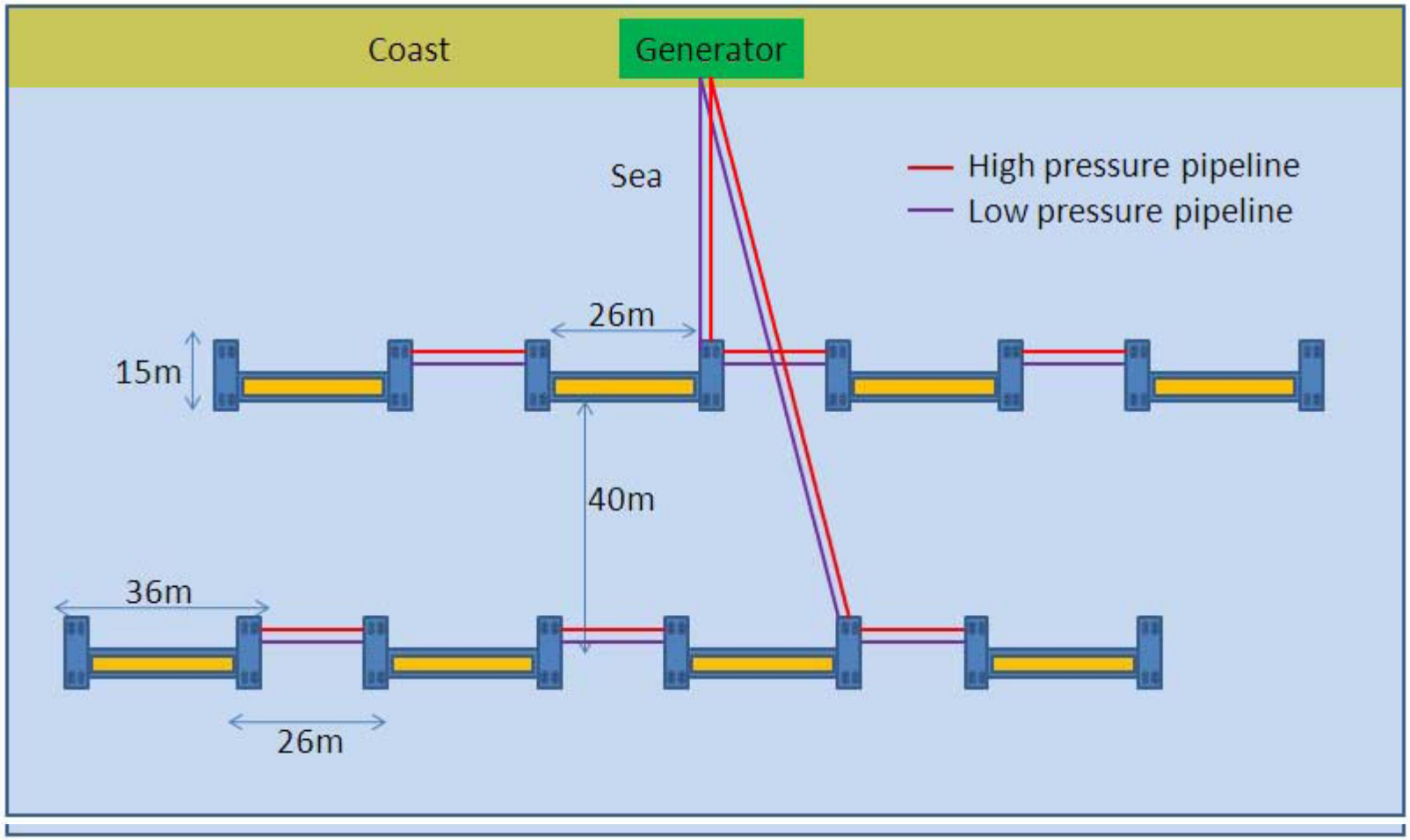
January 2013 - RME's FERC Preliminary Permit application approved



24 sq. mi. study area approved by FERC

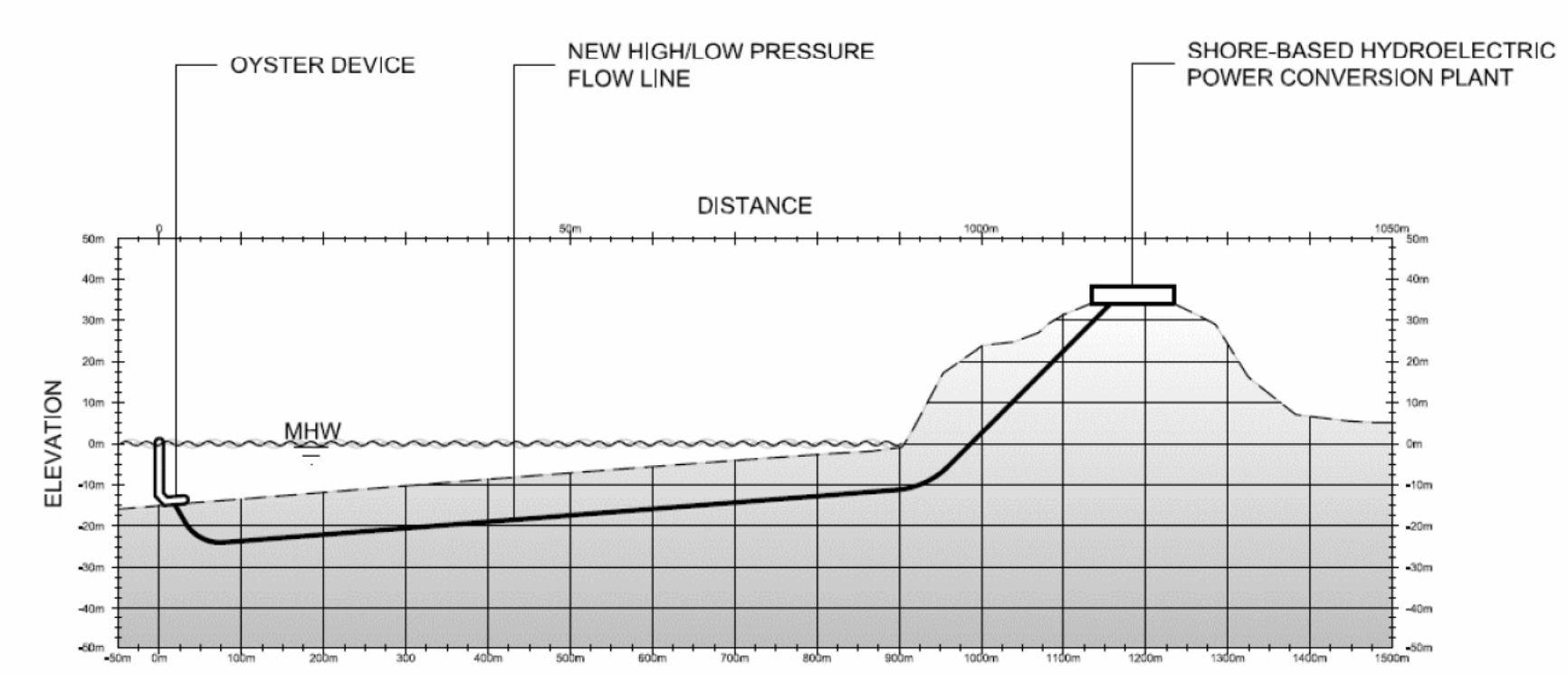


Potential Array Configuration (not to scale)



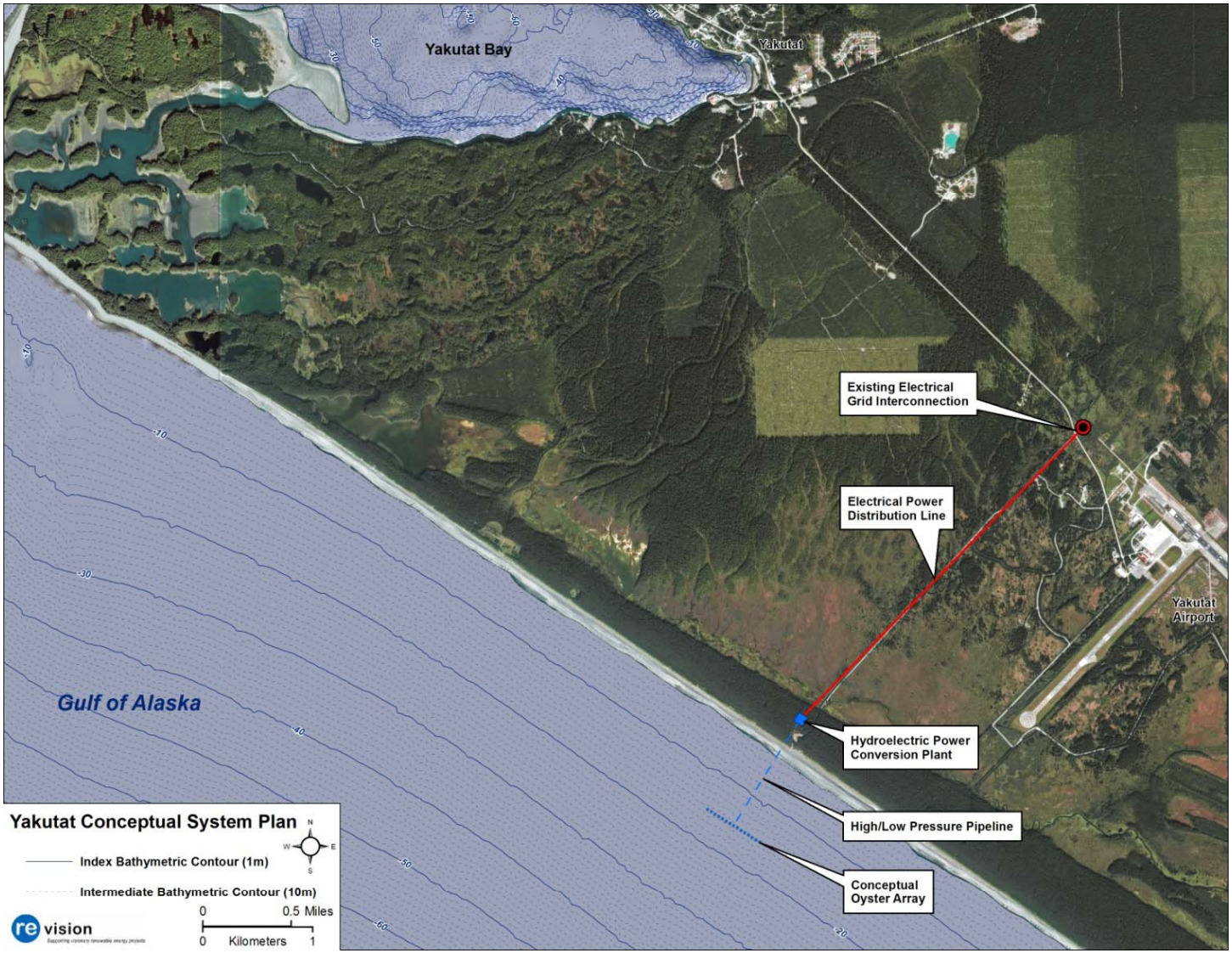
Note: Diagram from 2009 EPRI Study

Illustration of WEC-to-Shore Connection



Note: Diagram from 2009 EPRI Study

Potential Grid Connection Point (others to be studied)



Of Serious Concern (debris & sediment movement)

Project Details & TBD

- System to operate as a diesel fuel saver
- Will utilize SurgeWEC™ with 50 kW nameplate rating
- 10 to 15 SurgeWEC™ arranged in an array design TBD
- SurgeWEC™ pumps seawater to on-shore turbine/generator
- Power smoothing system will match diesel ramp rate
- Total project size - 500 kW to 750 kW

To be determined:

- Final device dimensions and anchoring methods
- Deployment depth and distance from shore
- Marine mammal, fish and wildlife impact
- Impact on seabed dynamics
- Project cost - LCOE

FERC Licensing

RME will pursue Pilot License – basic terms include:

- Small (5 MW or less) project
- Deployed for a five to ten year license term
- Cannot be located in environmentally sensitive areas
- Must agree to shut down or removal if significant adverse environmental impacts are observed
- Must be removed at the end of pilot license term, or file for long term license
- Must consult with agencies regarding studies and post-deployment monitoring plan
- Must engage broad base of stakeholders
- Must prepare and submit a draft pilot license application
- FERC must prepare an environmental assessment of the proposed project

Project Timeline

July 2013 – Commence site evaluation & environmental studies

March 2014 - Final system design process commences

May 2014 - SurgeWEC™ fabrication commences

July 2014 - On-site construction commences

September 2014 – Deploy & commission one SurgeWEC™

July 2015 – Deploy & commission remaining SurgeWECs

Principal Research Studies & Funding Sources

Three major studies contemplated:

1. **Fish & marine mammal impact study**
   - **Team: RME , PNNL, NOAA, City & Borough of Yakutat**
2. **Wave resource assessment/seafloor dynamics**
   - **Team: RME, USACE, Benthic Geoscience, U. Alaska Fairbanks**
3. **Civil Engineering/Grid Integration**
   - **Team: CBY + Alaska Energy & Engineering**

THANK YOU!