



Overview of Engineering Considerations for Siting and Risk Management for Successful Wind Energy Development, Offshore U.S.

Briefing for:
North Carolina Offshore Wind Task Force
November 5, 2010

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- Fugro is the world's largest and most technologically-advanced firm that:
 - collects, interprets, and analyzes data from and below the earth's surface
 - provides advice for the development of projects based on that data.
- The primary supplier of such services to:
 - the offshore Oil & Gas (O&G) industry in the Gulf of Mexico (since the late 1940s) and around the world
 - European offshore wind industry
- Services provided to OW industry
 - Subsurface investigation & foundation design
 - Geophysical, geohazards surveys
 - Met-ocean consultation
 - Meteorological tower investigation, design, and installation
 - OWF substructure installation
 - Cable installation pre- & post-lay surveys



Siting Considerations & Engineering-related Project Risks



- Four Elements of Siting Evaluations:
 1. Wind Resource
 2. Ocean Usage
 3. Environmental Constraints
 4. Engineering Development certainty/uncertainty (risk)
- Being the 4th consideration, engineering aspects have often been of (too) low priority or have been neglected until too late
- This was a fundamental *Lessons Learnt* in Europe
- How engineering fits into the project's siting – planning – investigation – design – construction – operations sequence should be recognized when developing an RFI



Navigating the Regulatory Maze

- U.S. Dept of Interior, Bureau of Ocean Energy Management Regulation and Enforcement (formerly the Minerals Management Service)
 - Decades of experience regulating offshore Oil & Gas
 - Lack of experience or technical codes & standards for offshore wind
 - Recognition that existing offshore wind experience does not include hurricane loading
 - Considers the East Coast a *Frontier Area*
 - No historical energy development and installation of structures
 - A long-term experience base of how structures perform does not exist
 - Caution is therefore justified

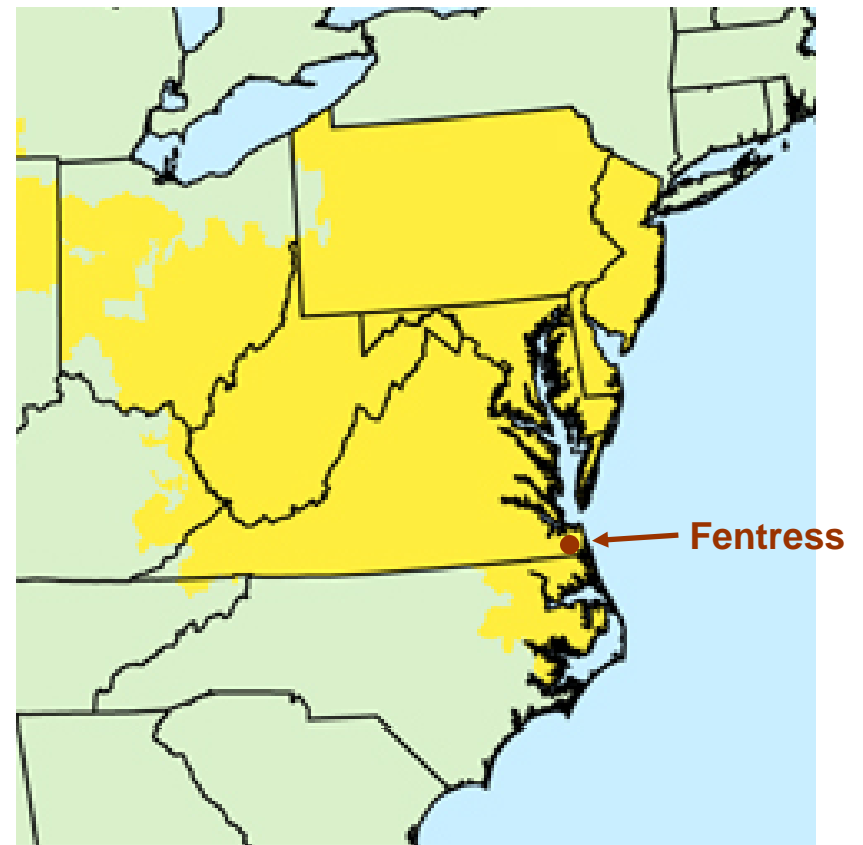


*The joy of being a pioneer is to find
your way where others have yet to go*



Potential Opportunities Offshore NE North Carolina

- PJM distribution system includes NE North Carolina
- PJM system can receive power at Fentress substation
 - Fentress reportedly has the greatest capacity to absorb power of any coastal location on East Coast
 - Direct connection to existing 500 kV
- Coast offshore NE North Carolina less affected by hurricanes than SE-facing coast
- Could this be a potential avenue for advocacy of a regional approach ? (rather than state-by-state competition)





Lessons Learnt in Europe

- What you can not see, can hurt you
 - Subsurface conditions, and their variability often under appreciated or not appreciated in a timely manner – increased costs & delayed schedule
 - Some OWFs sited on areas where sea and seafloor dynamics are extreme resulting in chronic scour – increases loads on foundation, increase foundation movement and changes foundation period
 - Some deficiencies in design not apparent for several years – e.g., slippage across grout interface between tower and foundation
 - Will further time and cycles of load reveal other weak links?
- Lack of appreciation of environmental loads and subsurface conditions (and variability) led to bad assumptions
 - Too conservative (and costly) or unconservative (and risky) foundations
- Offshore wind is not an incremental step from land

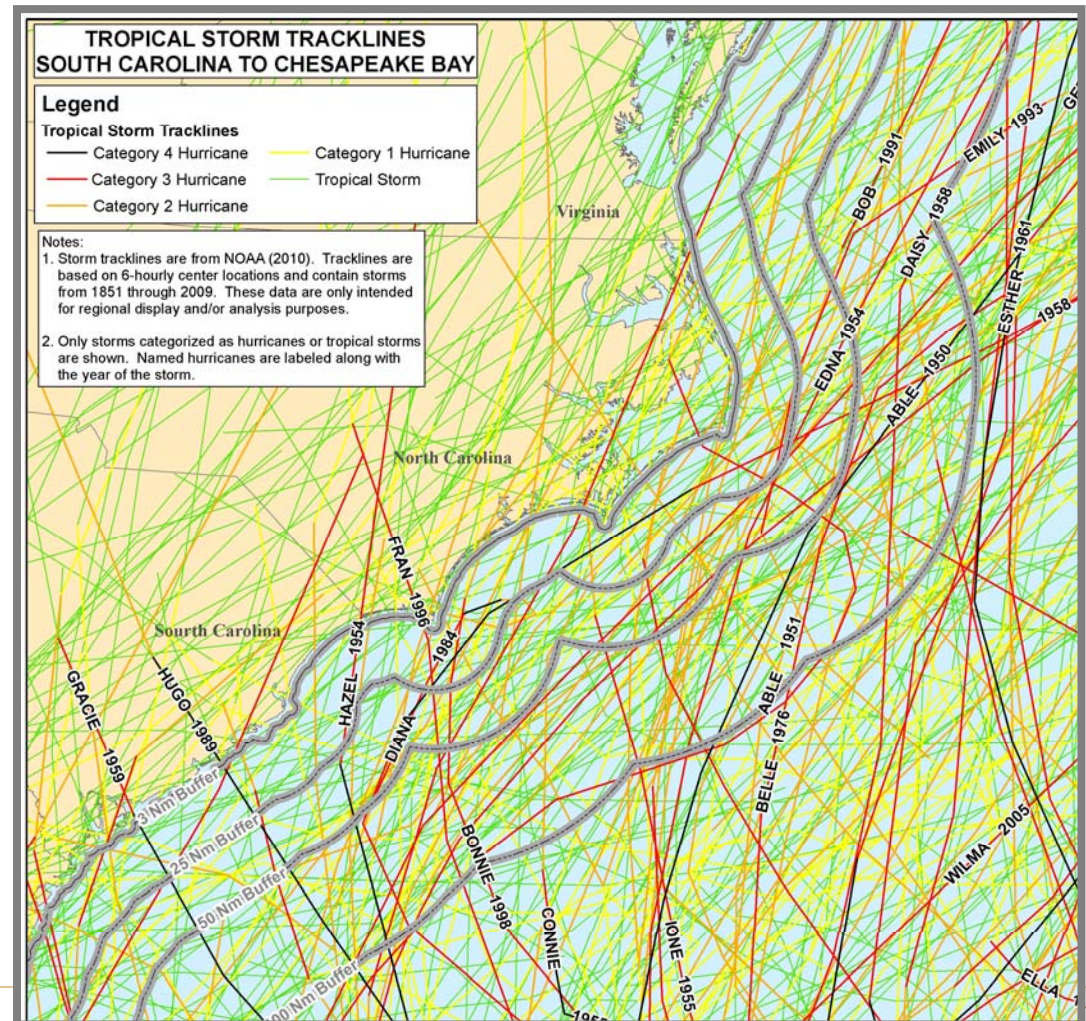


The ocean is an unforgiving environment

What are the Implications of European Experience for Wind Development Offshore North Carolina ?



- What are the implications for OWF site and RFI areas re: **Environmental Loads**
- Extreme wind and wave loads off NC higher than in Europe due to Hurricanes
- BOEMRE considers this to be of the highest importance
- Cape Hatteras provides a barrier island to the ocean farther to the north
- Hurricanes speed up and lose energy as they move north
- Thus hurricane exposure to the north of Hatteras should be less than to the south

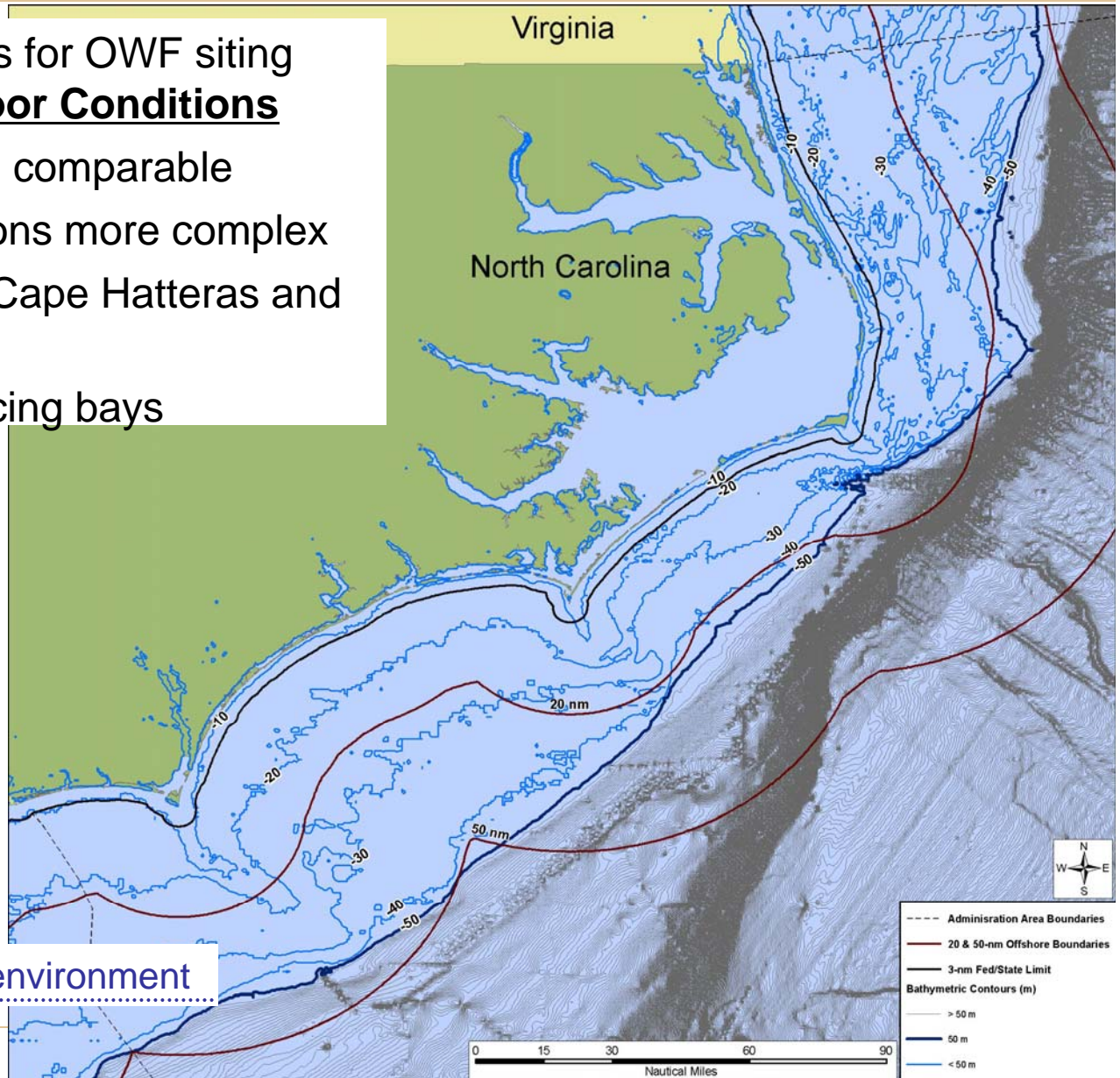
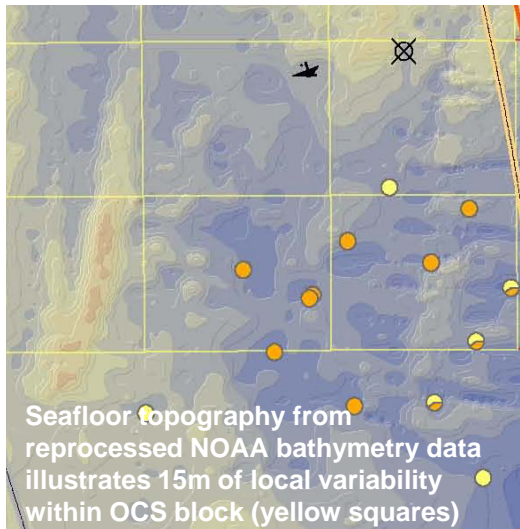


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What are the Implications of European Experience for Wind Development Offshore North Carolina ?



- What are the implications for OWF siting and RFI areas re: **Seafloor Conditions**
- Regional seafloor slopes comparable
- Local bathymetry variations more complex
- Likely most complex off Cape Hatteras and other, lesser Capes
- Least complex off SE-facing bays

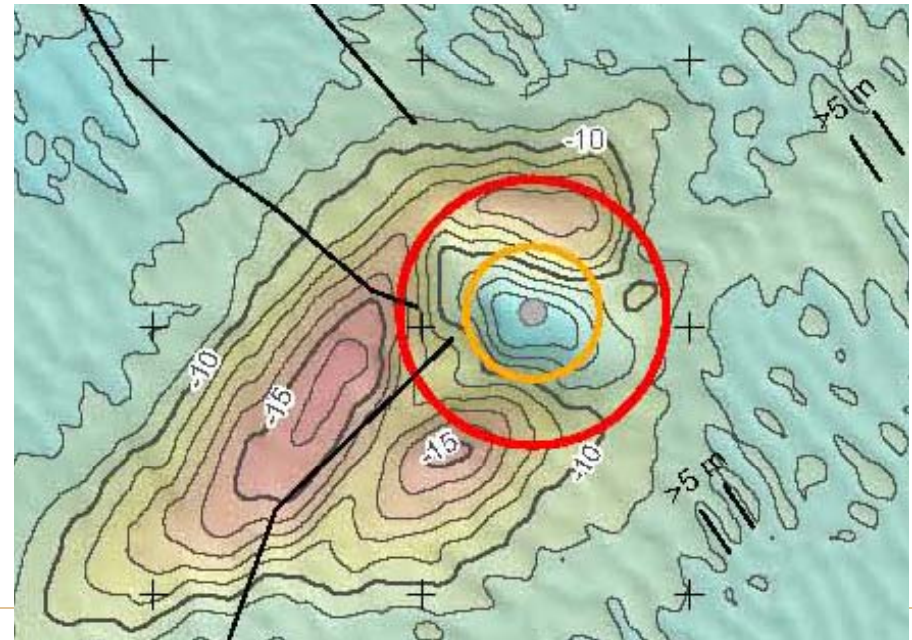
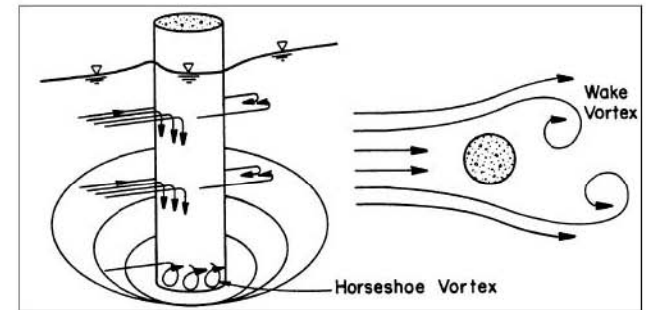


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What are the Implications of European Experience for Wind Development Offshore North Carolina ?



- What are the implications for OWF site and RFI areas re: **Seafloor Sediment Mobility and Scour**
- Currents producing seafloor sediment mobility and scour anticipated to be as extreme (or more so) that at most European sites
- Is an anticipated condition (and a concern of BOEMRE) off the east coast
- Cape Hatteras area is probably the extreme conditions on the east coast
- Other capes and inlets also expected to create increased currents and scour
- Seafloor variations, at least in part, due to this consideration
- Increase foundation movement & changes foundation period



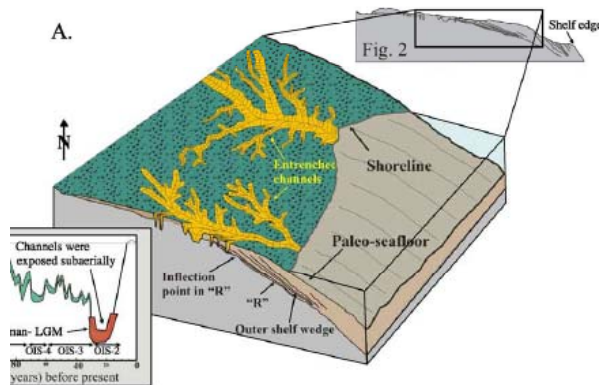
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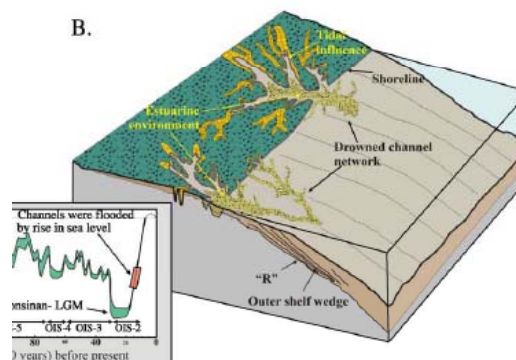


- What are the implications for OWF site and RFI areas re: **Subsurface Conditions**
- Very little meaningful engineering data (i.e. it's a Frontier Area)
- Quality and robust data will be required (for design and to satisfy BOEMRE)
- Anticipate more variability than most would expect due to channelization during sea level low stands and backfilling when sea level rises

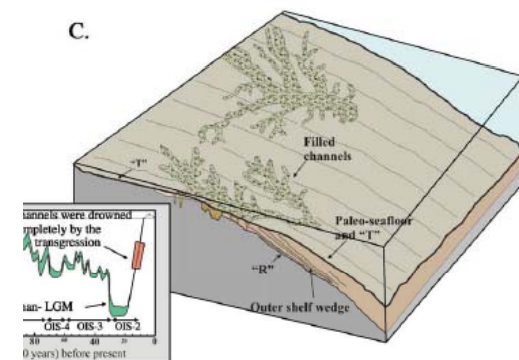
When sea level is low, what is now the shelf is exposed, rivers carve valleys across the shelf



As sea level rises, the valleys are flooded, and filled with sediment



Today, the drainage network is buried & beneath the seafloor masking subsurface complexity



- Thickest deposits of poorer clay sediments off drainage outlets

Subsurface variations occur at various scales below a potential OWF Site

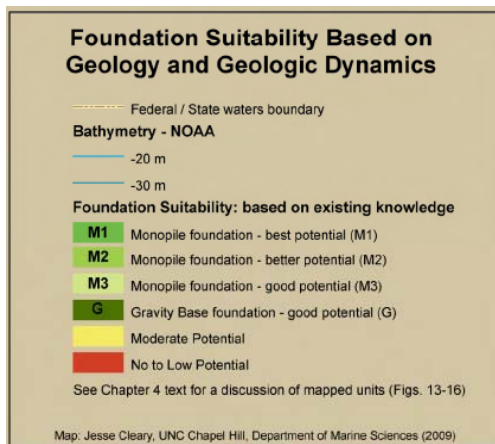
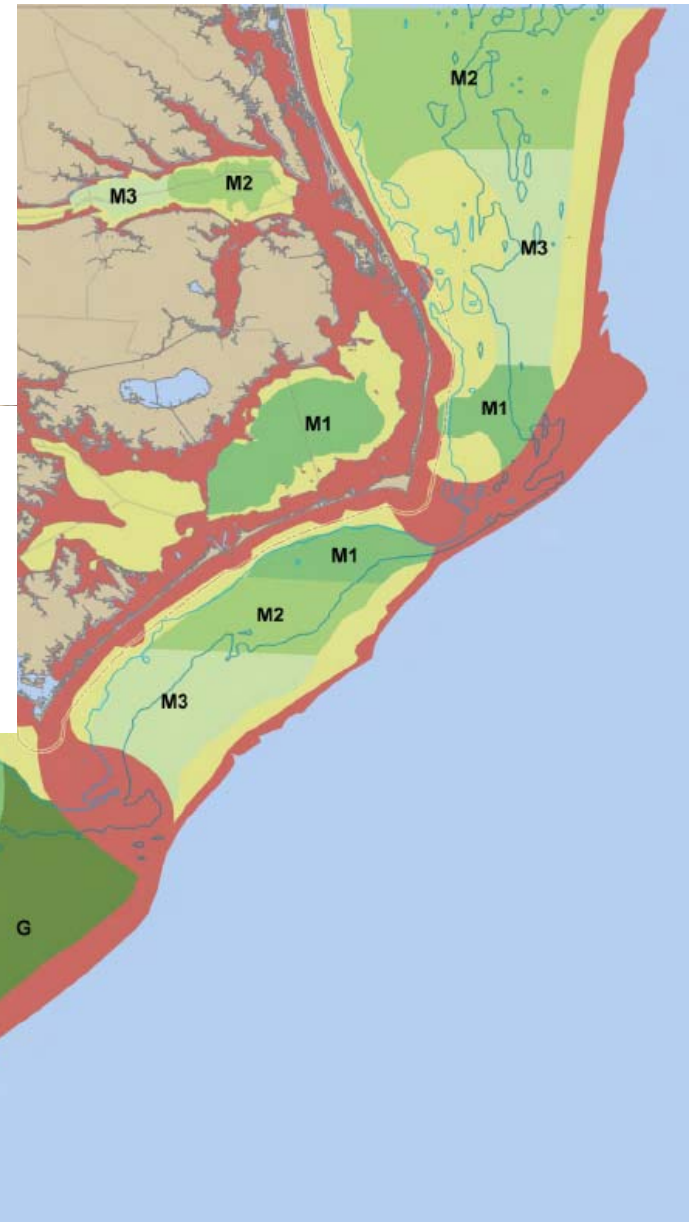
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Thoughts relative to North Carolina RFI

- UNC Study provides a valuable broad overview
- Significant detail needs to be added for project siting – permitting – design – installation – operations to move forward
- Need to recognize:
 - Variations of seafloor and subsurface over OWF area
 - Local seafloor and subsurface conditions likely to eliminate some areas within an OWF area
- Foundation suitability evaluation is overly broad
- Caution re: overly restricting RFI area based on broad, very high altitude initial evaluation



Conclusions

- Although engineering factors may be the 4th and last constraint on siting, their impact should not be underappreciated or overlooked
- RFI areas should be defined recognizing probability of local environmental, archaeological and physical considerations that will create exclusion zones within OWF-size development areas
- Potential advantages of the opportunity to deliver energy to the PJM grid at Fentress



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On behalf of Fugro, I appreciate the opportunity to present these thoughts, and look forward to future opportunities to advocate the development of offshore wind energy in the U.S.

Thank You

