Qualitative Well Integrity Risk Assessment for Carbon Storage in the Gulf of Mexico Depleted Fields

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Outline

Overview of Offshore Well Integrity

- Scope
- Summary of Risks
- Review of Offshore Well Integrity Analyses

Methodology

- Case Study Areas
- Data Collection
- Well Integrity Risk Assessment Workflow - risks and impacts

Case Studies

- Summary risk results with risk matrices

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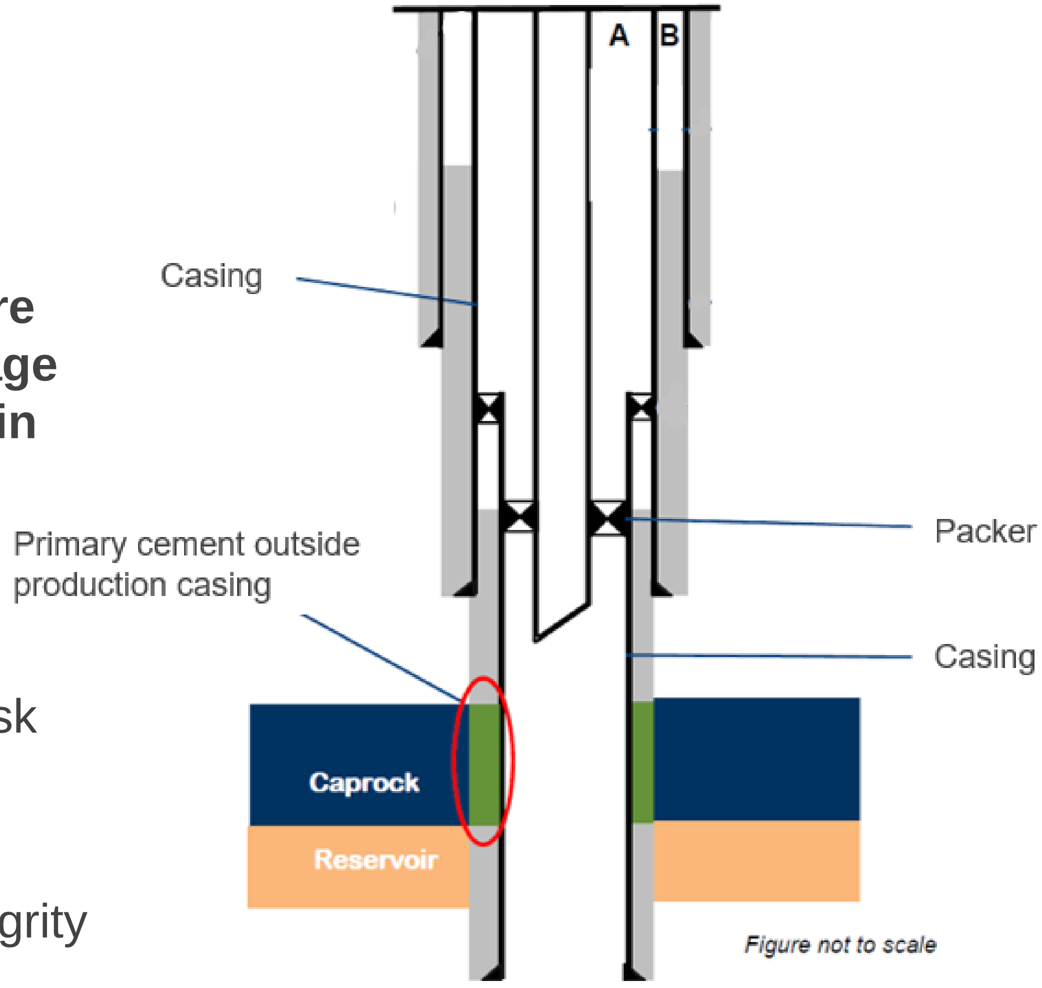
Scope

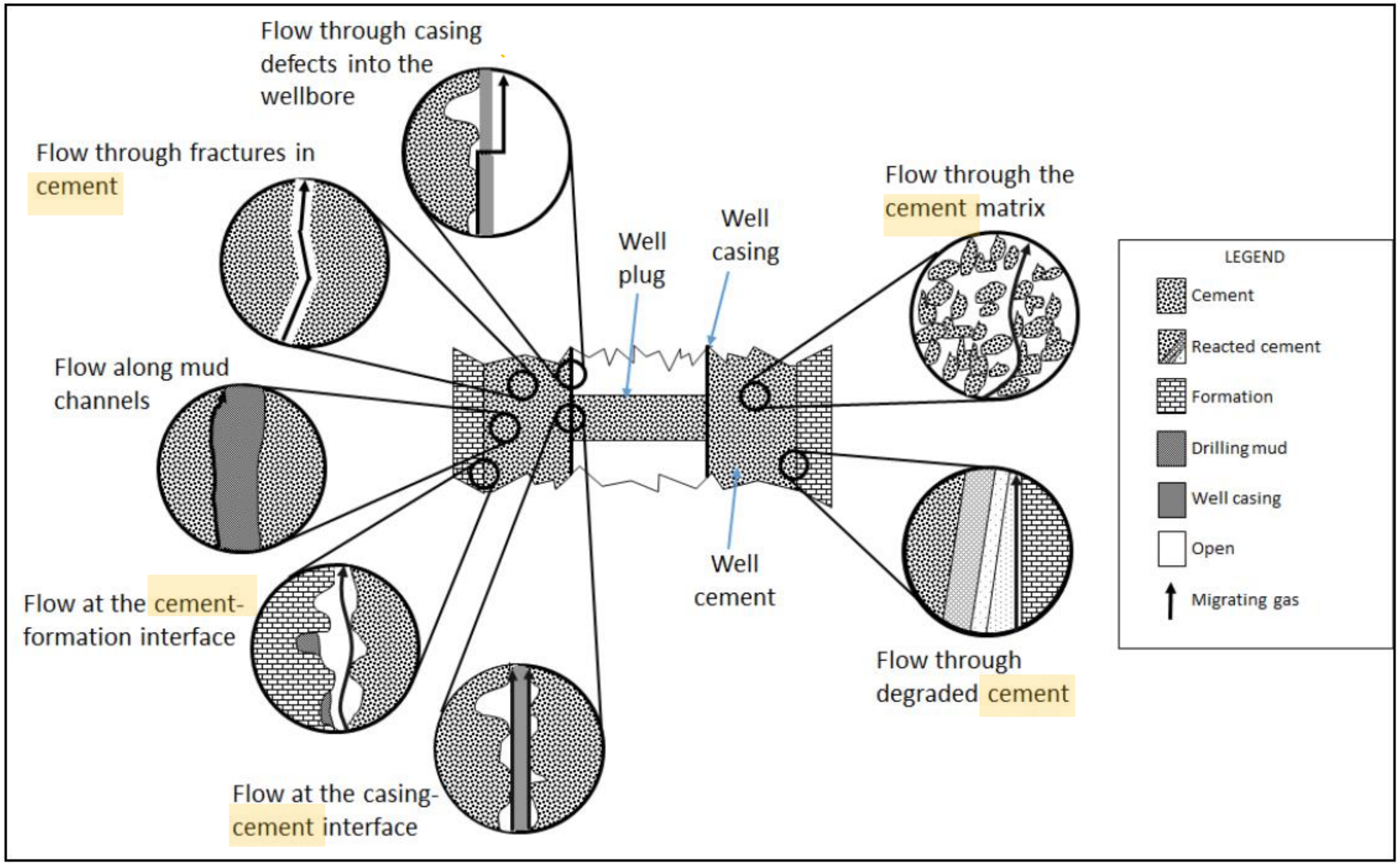
- To enable safe CO_2 storage in offshore reservoirs:
- **Develop a qualitative risk assessment for ranking wellbore integrity for potential CO_2 storage applications from well records in depleted fields**
    - Initial scoping tool, not considering reuse of wells
    - Identify high risk wells, low risk wells, and data gaps
- Wellbore cement integrity is important, followed by casing integrity
- Can be applied to prospective sites in the rest of Gulf of Mexico



Adapted from Akemu, Mersemann, Benedictus, 2011

Summary of Leakage Pathways at a Wellbore

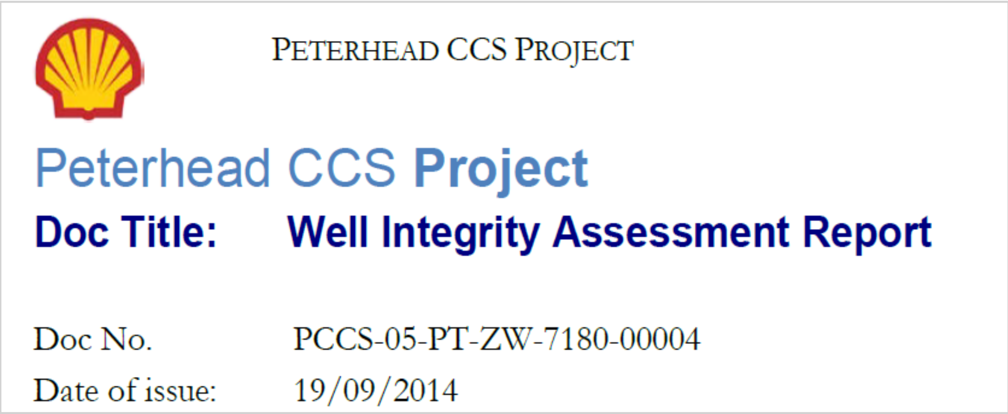
Leakage pathways could be from multiple cement defects, casing defects, at the well plug



Gasda et al., 2004

Other Offshore Well Integrity Analyses

- Australia, Netherlands, U.K
- REX-CO2
- Focus:
  - cement integrity at caprock and cement plugs, CBLs
  - casing information and any well competition defects (for reuse of legacy wells)


PETERHEAD CCS PROJECT

Peterhead CCS **Project**

Doc Title: Well Integrity Assessment Report

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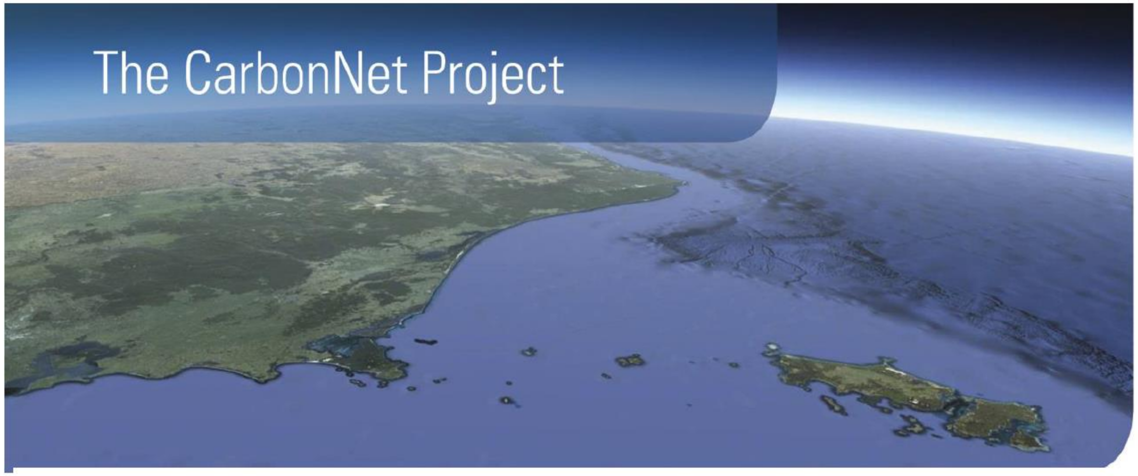
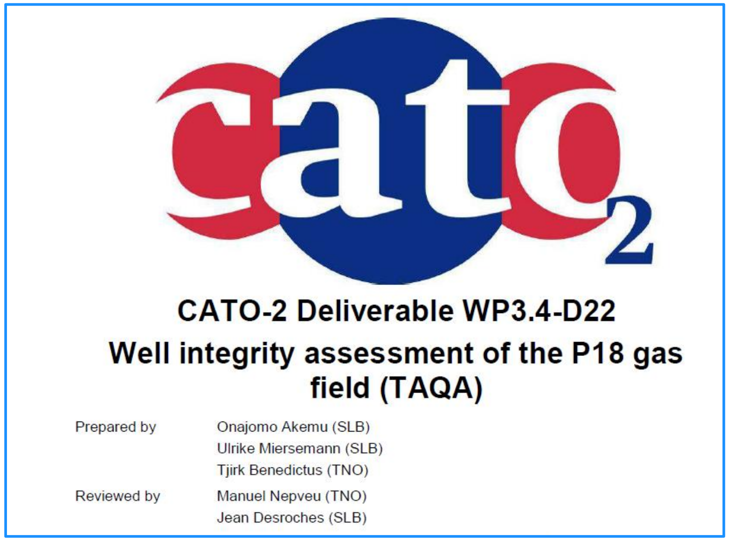
Date of issue:	19/09/2014




CATO-2 Deliverable WP3.4-D22

Well integrity assessment of the P18 gas field (TAQA)

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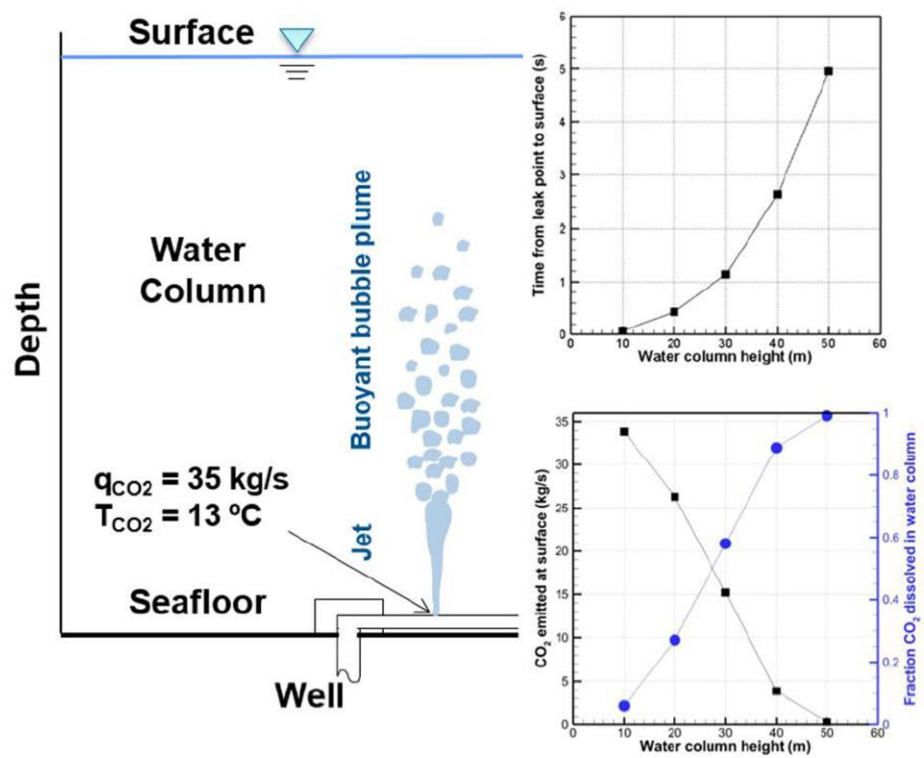
Reviewed by	Manuel Nepveu (TNO) Jean Desroches (SLB)

Integrity of Wells in the Near-shore Area Gippsland Basin Victoria

Offshore Well Leakage Impacts

Studies show CO2 disperses and dissolves quickly, but severity of impact is greater in certain habitats and could affect existing infrastructure based on depth of water

- GoMCARB study (Oldenburg and Pan; 2019, Oldenburg and Zhang, 2021)
    - >50 m depth CO2 attenuates in water
    - 10 m water depth with a large-scale blowout underway, hazardous CO2 concentrations to extend a hundreds of meters from the emissions source
- ECO2 EU Project - natural and artificial CO2 seeps in North Sea and the Mediterranean



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Methodology of Well Integrity Assessment

Data Collection of Case Study → Rank Risk Likelihood → Rank Severity of Impact →

Required Data

- Data requirements for a well integrity analysis were established
- Geologic data
  - Reservoir formations
  - Reservoir characteristics (depth, porosity, permeability)
  - Presence of caprock
- Well ID and Location Data
  - Well API numbers
  - Geographic location of wells
  - Longitude and latitude
- **Well Records**
  - **Well construction and history (age, depth, borehole diameter, casing, cement, blowouts, workovers etc.)**
  - **Well cement integrity (amount and location of cement, CBLs)**
  - **Well casing integrity (caliper log, SCPs etc)**
  - **Well status and production data**
  - **P&A plug data**

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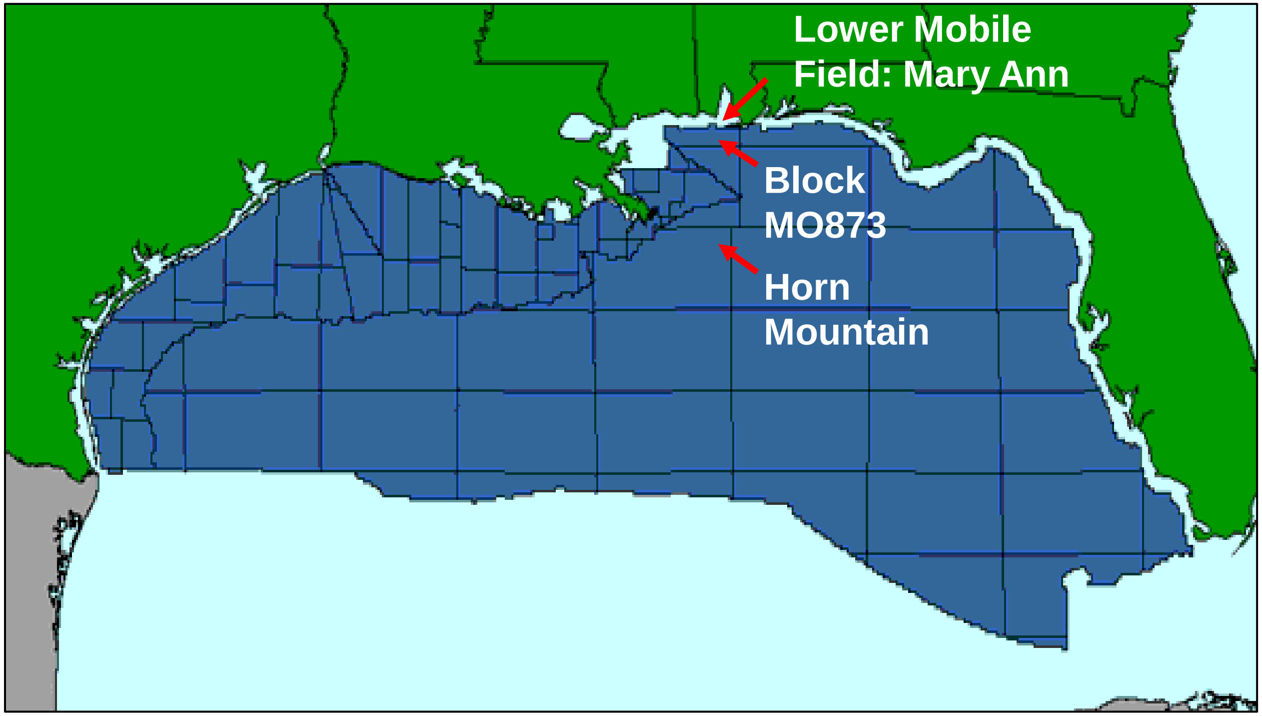
Case Study Areas

- Deepwater turbidite play
- Shallow continental deltaic sands
- Nearshore continental with deep Jurassic play
- Chosen to develop a methodology from range of wells
- Methodology can be applied throughout the rest of the study area



https://woodshole.er.usgs.gov/pubs/of2005-1071/htmldocs/catalog.htm

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Well Integrity Risk Assessment Workflow

Risk = Likelihood * Impact

Adapted from Duguid et al., 2017, 2021

Factors of Risk Likelihood	Low Risk (1)	High Risk (5)
Well Status	producing	P&A, dry, unknown, inactive, orphan
Well Deviation	low angle deviation	30º deviation or unknown
Well Depth	>10,000 ft	>25,000 ft, or in contact with HTHP conditions
Well Type	oil or gas well	water injection well
Well Density	no wells within 1000 ft	5 wells or more within 1000 ft
Gas Migration or Surface Casing Vent Flow	none	significant
Casing Failure History (SCP)	none	yes
Cement Quality/Location	appropriate thickness, through caprock, appropriate casing vs bit size, sufficient cement bond	not through caprock, inappropriate casing vs bit size, with unknown/insufficient cement bond
Cement Thickness through Caprock	100-75%	49-0% or unknown
Well Modifications and Sidetracks	no sidetracks/relevant modifications	3 sidetracks or more and/or integrity risk modifications
Casing Quality (caliper, corrosion, steel casing)	no washouts or corrosion known	corrosion, significant washouts, or unknown
Casing Connections	gas tight connection	inappropriate connection

P&A Factors of Risk Likelihood	Low Risk (1)	High Risk (5)
Cement Plug Criteria	sufficient plug thickness at caprock	no plug at caprock

Akemu et al., 2011; Bachu 2017; King and King, 2013; Kutcho et al., 2007; Lackey et al. 2017; Lackey et al., 2021; Shell UK Limited, 2014; Sminchak et al., 2018; van der Kuip et al., 2011; Watson, 2013; Watson and Bachu 2009

Risk Assessment

Risk = Likelihood * Impact

Three impact categories created to assess the severity of impact if there was a leakage within a certain proximity, maps are created for ranking

Impact	Notes	Low Impact (1)	High Impact (5)
Proximity to Environmentally Sensitive Areas*	MPAs, HAPCs, Seagrasses, Deep Sea Coral Habitats and Observations	No ESAs in proximity	Two or more ESAs
Water Depth	Thresholds based on Essential Fish Habitats and Leakage Simulations	>200 ft	<65 ft
Proximity to existing infrastructure/transit*	Transit, existing infrastructure such as pipelines	Low density transit, no infrastructure	High density transit and infrastructure

*Proximity within 0.7 miles -
Established from Oldenburg and Zhang, 2022; ECO2, 2016; and O'Reilly et al., 2022

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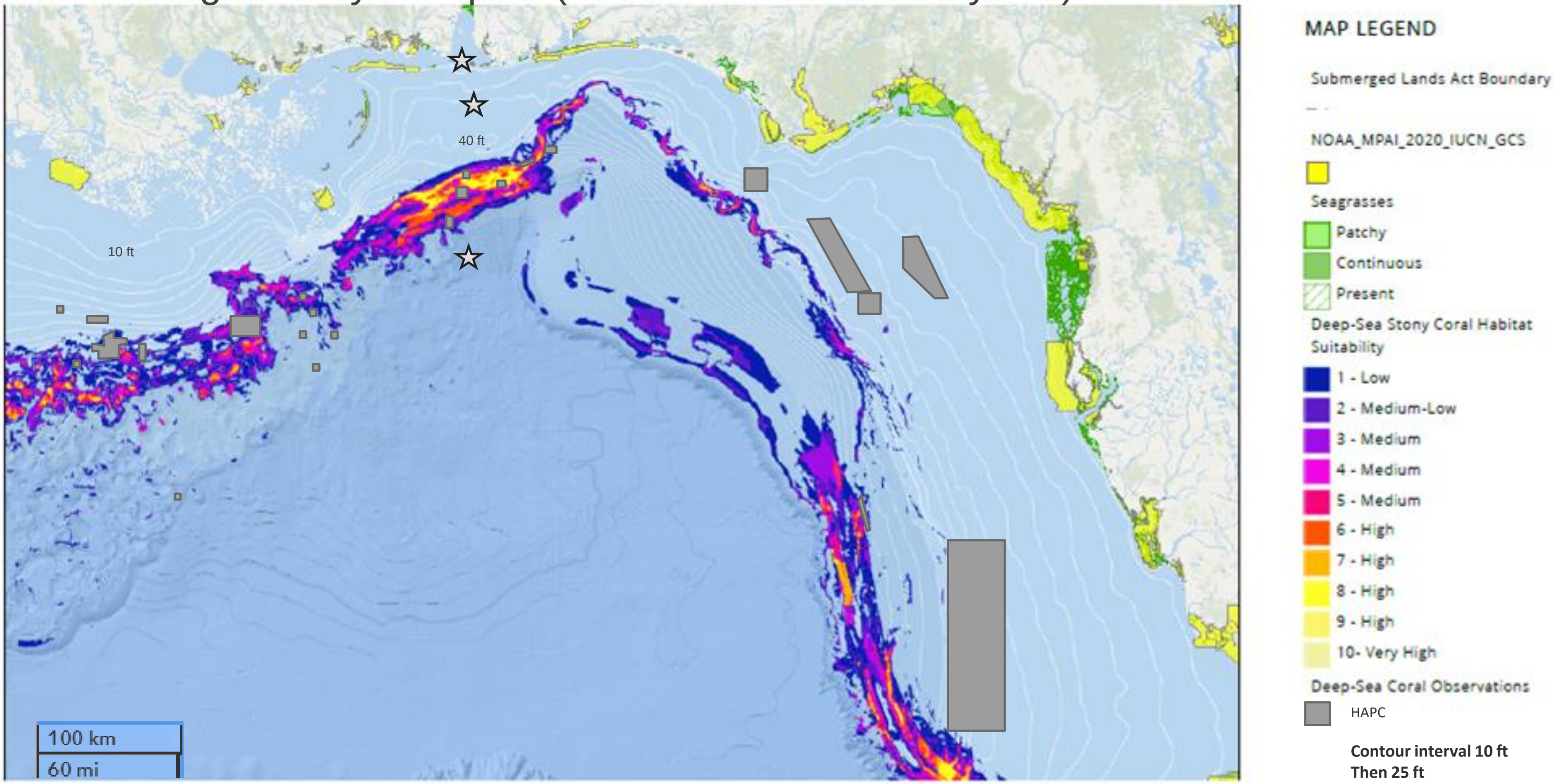
Proximity to Environmentally Sensitive Areas, Water Depth

For ranking severity of impact (star denotes case study site)

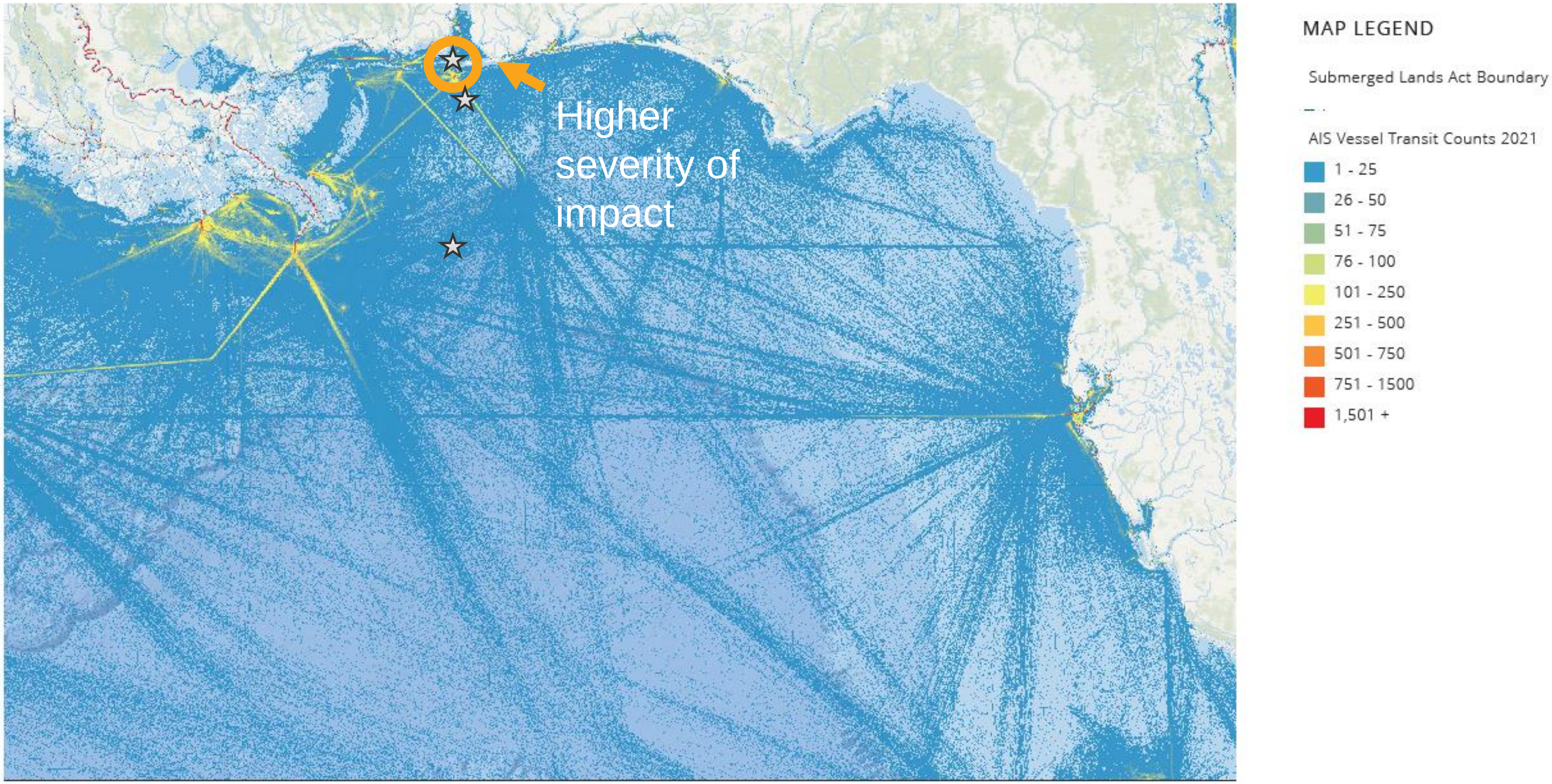


[Marine Cadastre National Viewer]

Transit Counts

For ranking infrastructure severity of impact (star denotes case study site)

BOEM
Bureau of Ocean Energy Management



[Marine Cadastre National Viewer]

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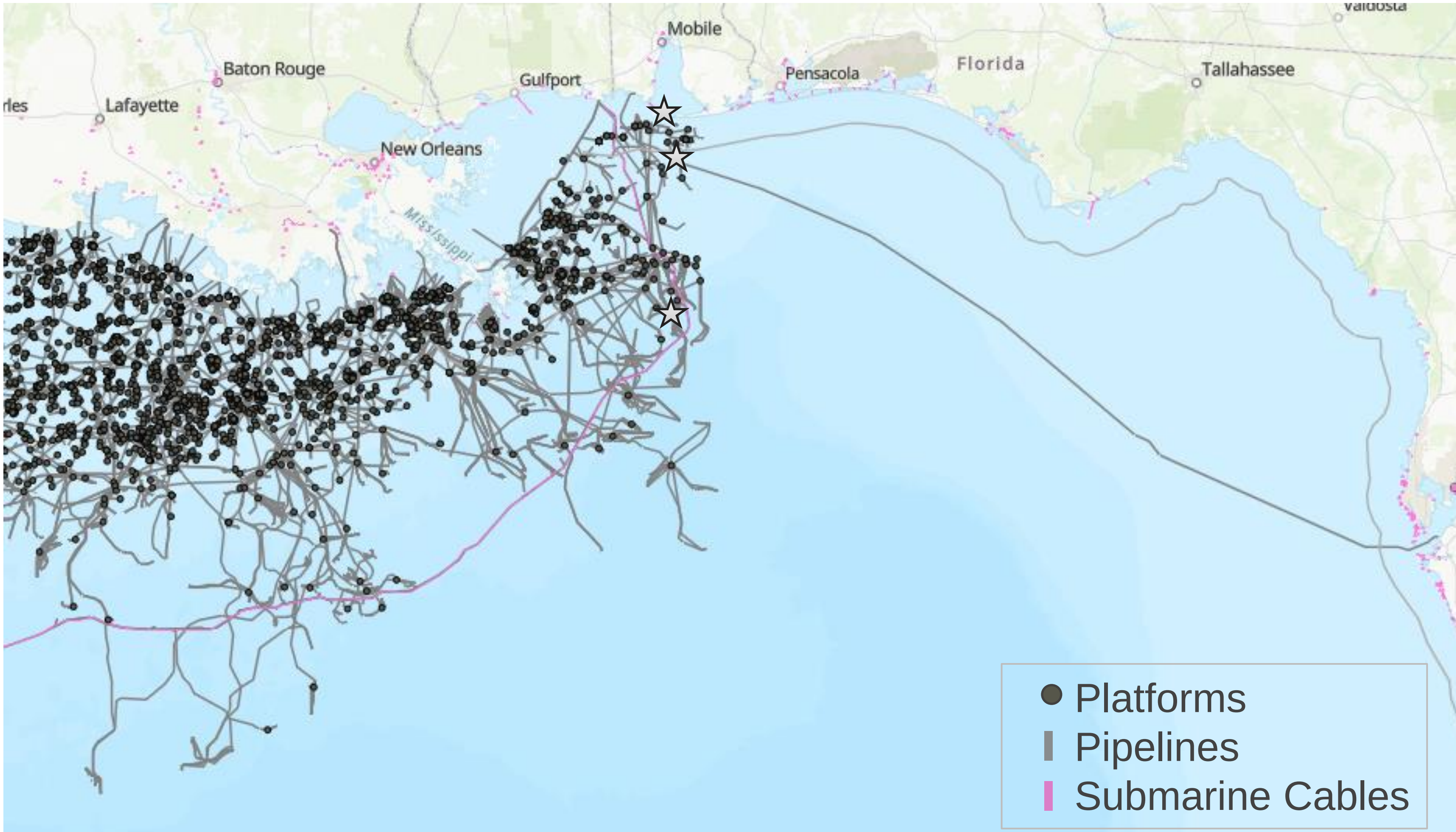
Infrastructure (Platforms, Pipelines, Wind)

For ranking severity of impact (star denotes case study site)



[Marine Cadastre National Viewer]

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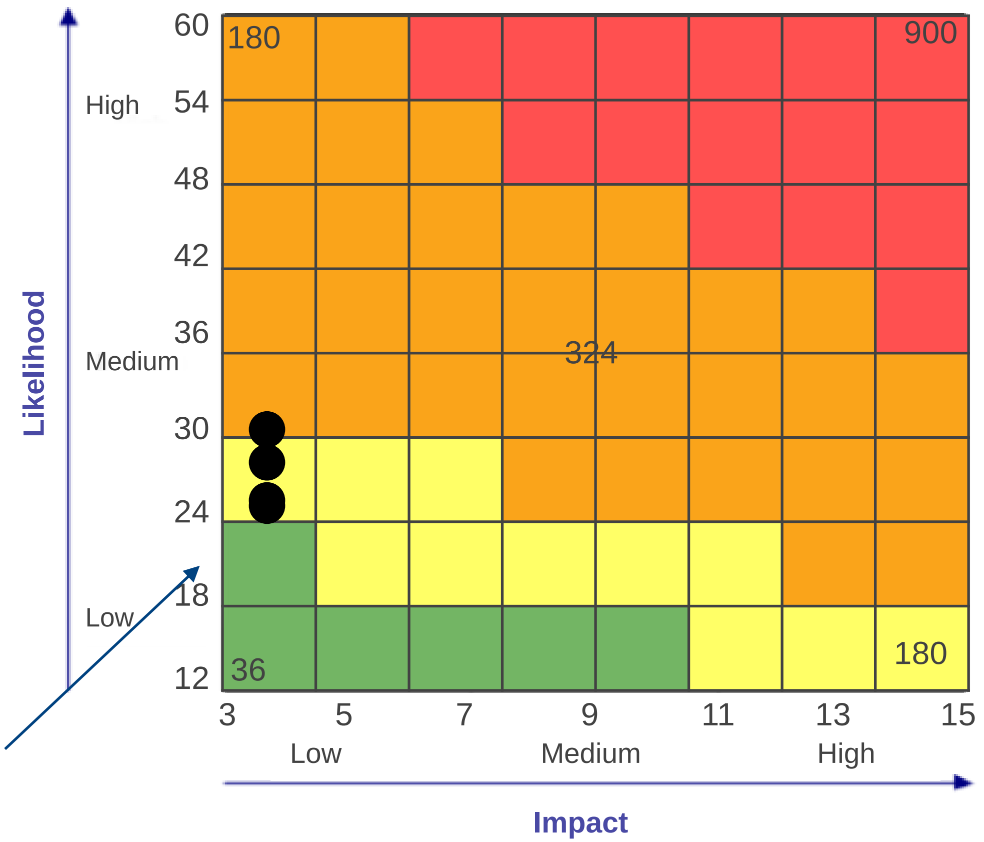
Well Risk Matrix

Low risk = low to medium impact and low likelihood

Medium risk = low to high impact and low to medium likelihood

High risk = low to high impact and medium to high likelihood

Critical risk = medium to high impact and medium to high likelihood



1st case study: potential well integrity issue in very few categories. TA wells, little missing data

P&A Well Risk Matrix

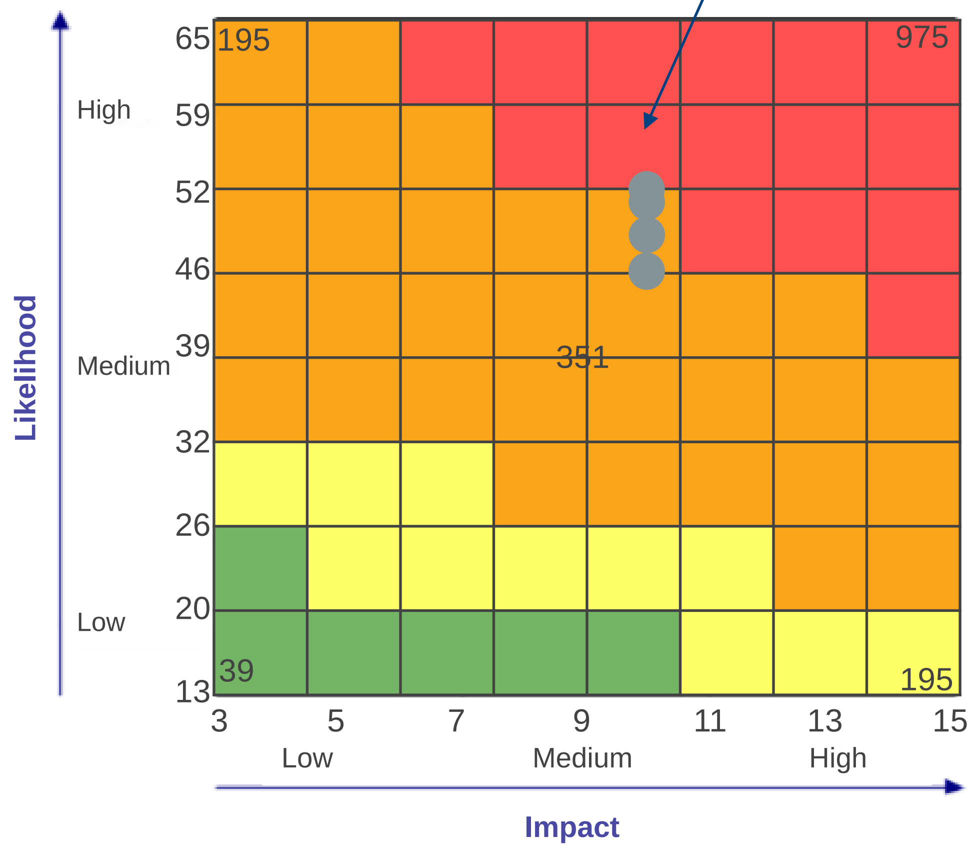
2nd case study: potential well integrity issues for several likelihood categories

Low risk = low to medium impact and low likelihood

Medium risk = low to high impact and low to medium likelihood

High risk = low to high impact and medium to high likelihood

Critical risk = medium to high impact and medium to high likelihood



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P&A Well Risk Matrix

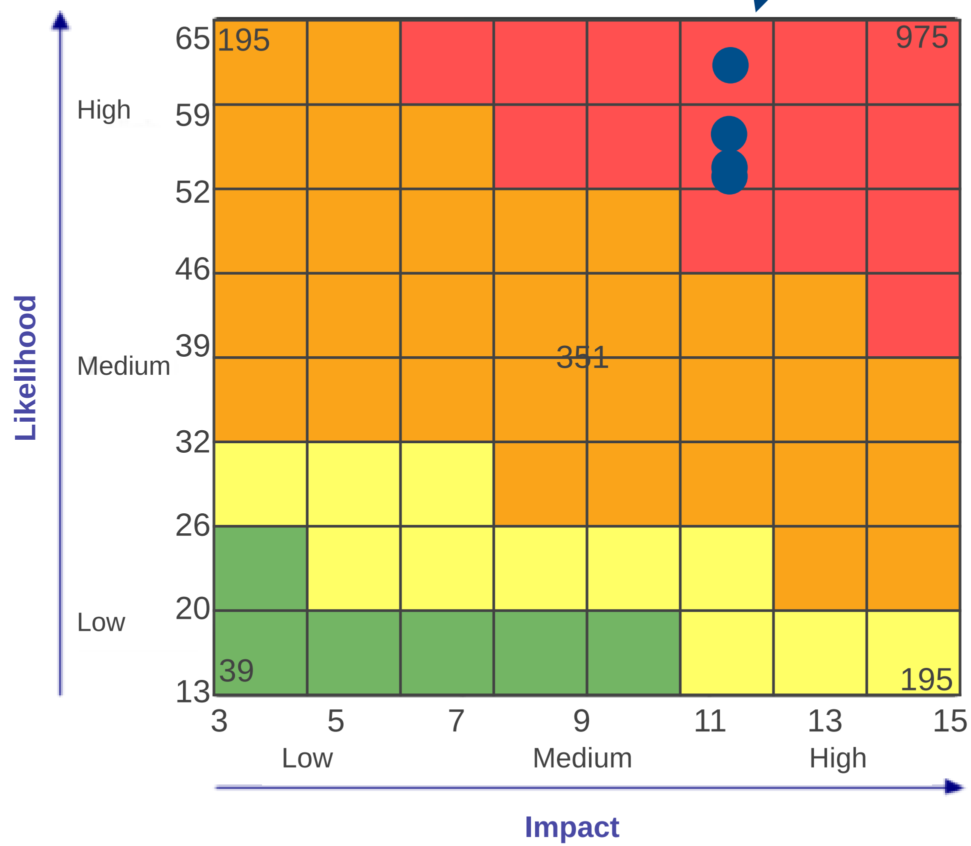
Low risk = low to medium impact and low likelihood

Medium risk = low to high impact and low to medium likelihood

High risk = low to high impact and medium to high likelihood

Critical risk = medium to high impact and medium to high likelihood

3rd case study: potential well integrity issues for most likelihood categories, many missing data files



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Summary of Case Studies and Next Steps

- **Legacy wells are a potential leakage pathway that have to be considered when scoping out carbon storage reservoirs**
- **Qualitative risk assessment is a systematic high-level scoping tool to start this process and identify low and critical risk wells, and where additional information is needed to assess risk**
  - Cement at caprock and cement plug data are important factors
  - 1st case study is relatively low risk, except wells with failed pressure tests and injection wells are higher risk, 2nd and 3rd case studies have higher severity of impact, older wells with more missing well files, and higher risk likelihoods
  - Missing data from old wells create a higher risk - FOIA Request
- Additional Considerations for next steps of analysis - site specific geological factors (gas hydrates, salt diapirs, faults) and details on proximity and concentration of CO2 plume

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Acknowledgements

BOEM

BSEE

Advanced Resources International, Inc.

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It can be done

Thank you
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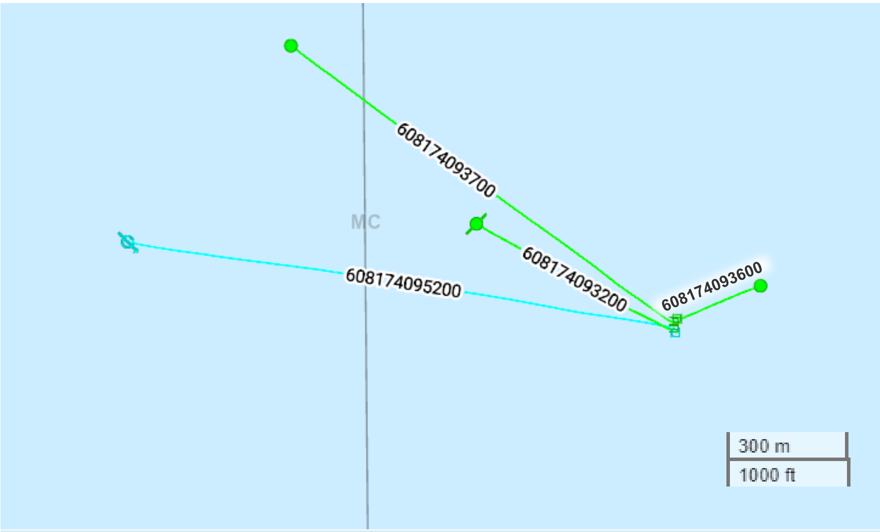
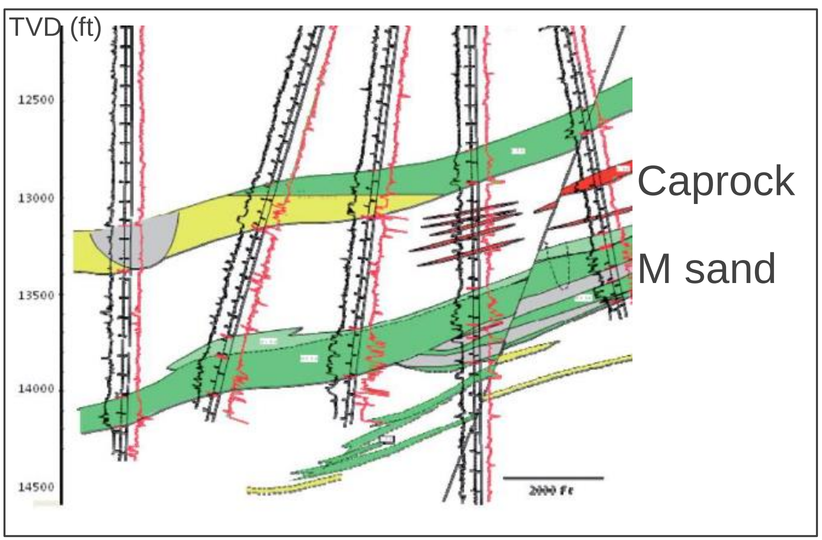
Deepwater Case Study: Overview



- Horn Mountain - Miocene turbidite sands with recent history of oil and gas production
- Caprock is ~ 600 ft of mudstones above the M sand carbon storage target (ARI)
- Proximal to several other wells



Well	Spud Date	TVD (feet)	Comments	Status (BSEE)	Status (Enverus)
A002	2001	13770	gas lift after initial production	TA	Active
A003	2001	14248	gas lift after initial production	TA	P&A
A004	2001	14241	gas lift after initial production	TA	Active
A006	2001	14515	water injection well	TA	P&A

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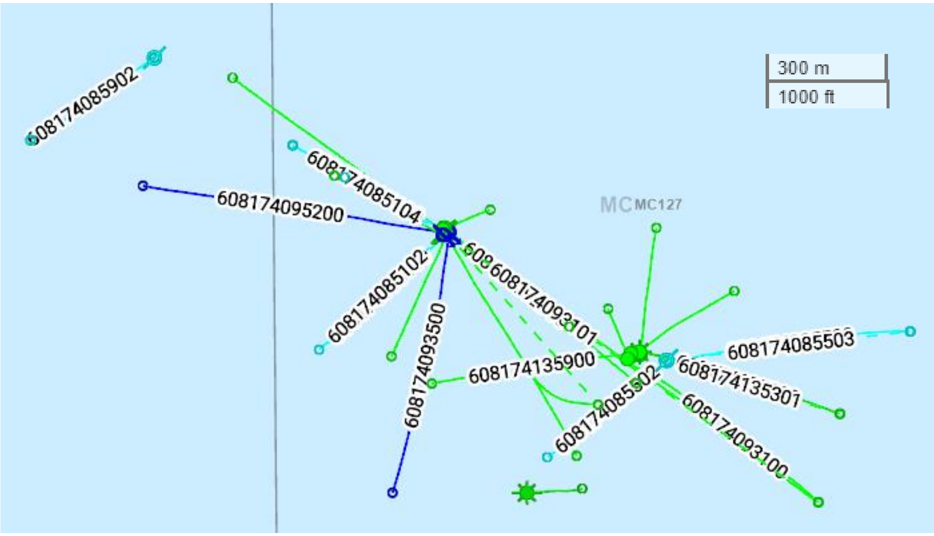
Deepwater Case Study: Overview



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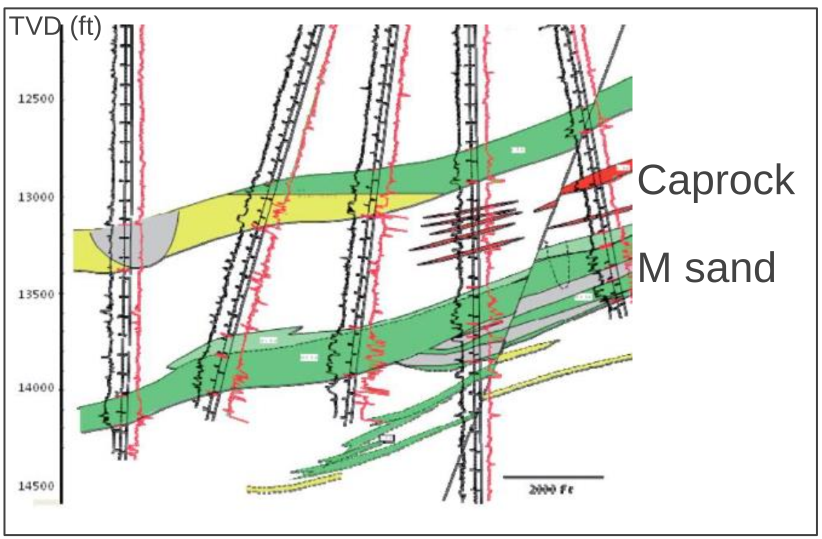

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A006	2001	14515	water injection well	TA	P&A

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Deepwater Case Study: Risk Assessment

Overall wells are low risk, except A003 with the casing failure history and A006 water injection well

Factors of Risk Likelihood	Low Risk (1)	A002	A003	A004	A006
Well Status	producing	2	2	2	2
Well Deviation	low angle deviation	2	2	2	2
Well Depth	<10,000	2	2	2	2
Well Type	oil or gas well	1	1	1	5
Well Density	no wells within 0.5 mi	5	5	5	5
Gas Migration of Surface Casing Vent Flow	none	5	5	5	5
Casing Failure History (SCP)	none	1	5	1	4
Cement Quality/location	appropriate thickness, through caprock, appropriate casing vs bit size with good bond	1	1	1	1
Cement Thickness through caprock	100-75%	2	1	2	1
Well Modifications and Sidetracks	no sidetracks or modifications	1	1	1	1
Casing Quality	no washouts or corrosion known, anti-corrosive steel used	2	2	2	2
Casing Connections	gas tight connection	1	1	1	1
Total Risk Likelihood		25	28	25	31
Total Impact		4			
Risk Score		**100**	**112**	**100**	**124**

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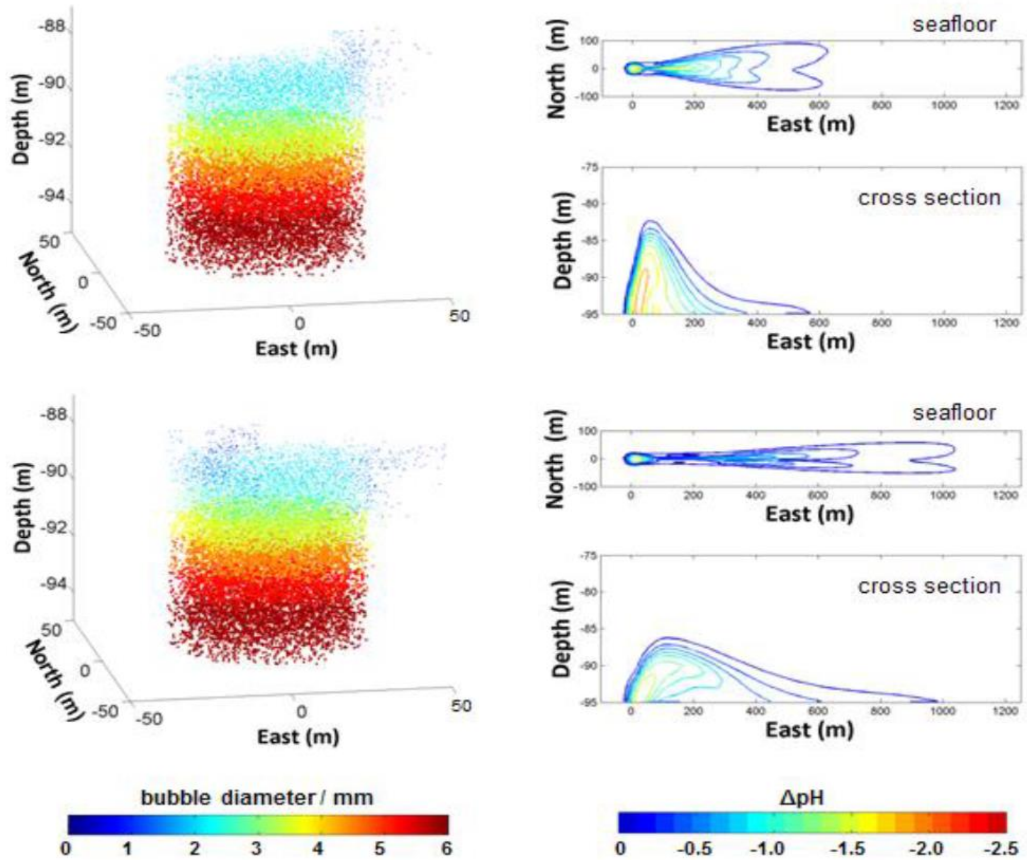
Impact – CO_2 Leakage

- Study simulated in North Sea - worst case scenario and current velocity of 10 cm/s and 20 cm/s (55,000 tonnes per year leakage in 25 m radius)
    - Gulf – 5 to 10 cm/s
- CO2 dissolves and disperses quickly – bottom waters affected 15 m (49 ft) above leakage at a distance of 600 to 1000 m (0.37 to 0.62 mi)
- **Thus, legacy wells within 0.7 miles in shallow waters (less than 65 ft) and could have a higher impact**



ECO2 Project

ESAs	Notes
Marine Protected Areas (MPAs)	Around coastlines and barrier islands, includes National Park Service, US Fish and Wildlife Service, NOAA's Estuarine Research Reserve, NOAA National Marine Sanctuary program, and states
Habitat Areas of Particular Concern (HAPC)	GoM and Highly Migratory HAPCs (blue fin tunas, sharks, swordfish, and billfish)
	GoM HAPC (Miss Canyon 118, Coral HAPC)
Essential Fish Habitat (EFH)	"includes coral reefs, kelp forests, bays, wetlands, rivers, and even areas of the deep ocean that are necessary for fish reproduction, growth, feeding, and shelter"
Deep Sea Coral Habitat Suitability and Deep Sea Coral Observations	Stony or Soft coral
Biologically Important Areas (BIAs) for Crustaceans	small and resident population
Beach Nourishment Projects	Replenishing sand lost to erosion creates safer marine life habitats and cuts down on hazards along the beach. Renourishment projects lead to greater sustainability for the beach and the surrounding areas
Seagrasses	nursery habitat, shells/skeletons can dissolve with acidic water
National Marine Sanctuaries	near national monuments near florida