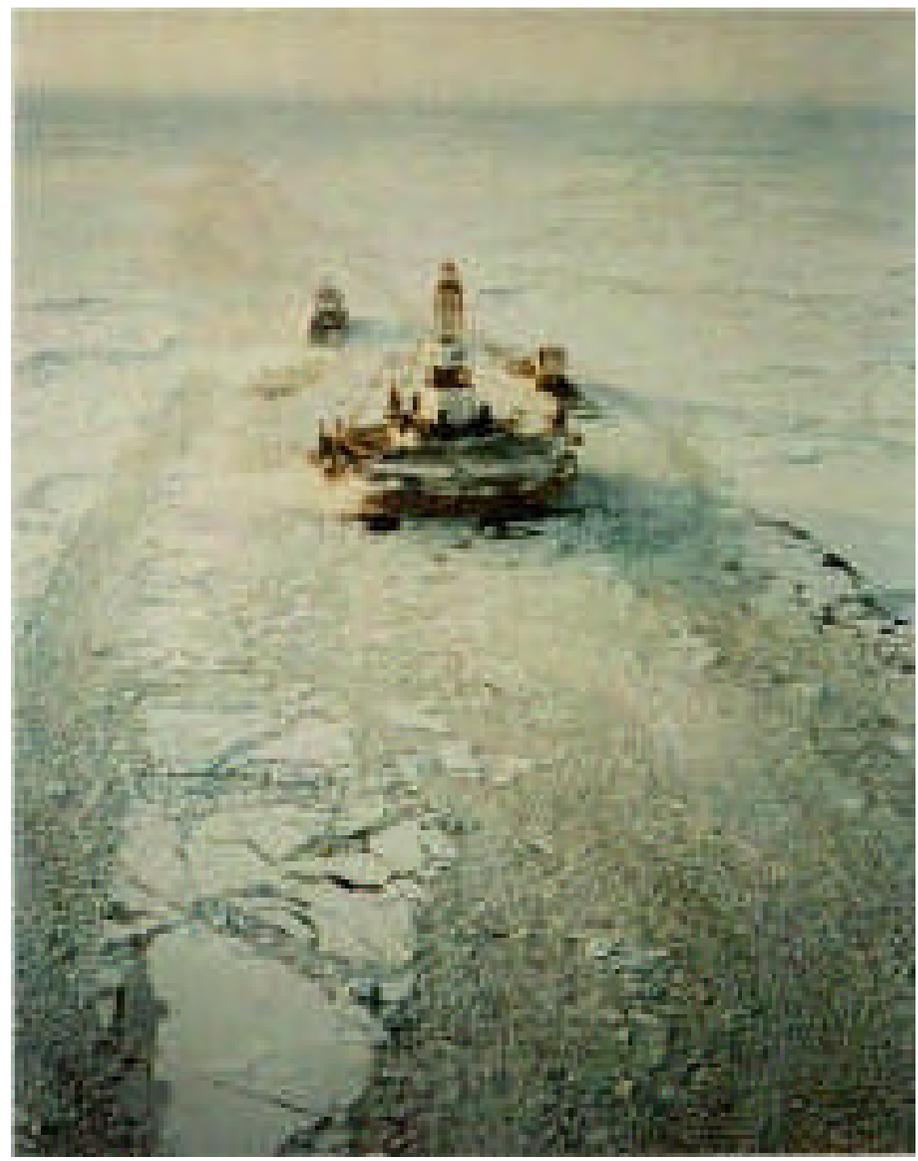
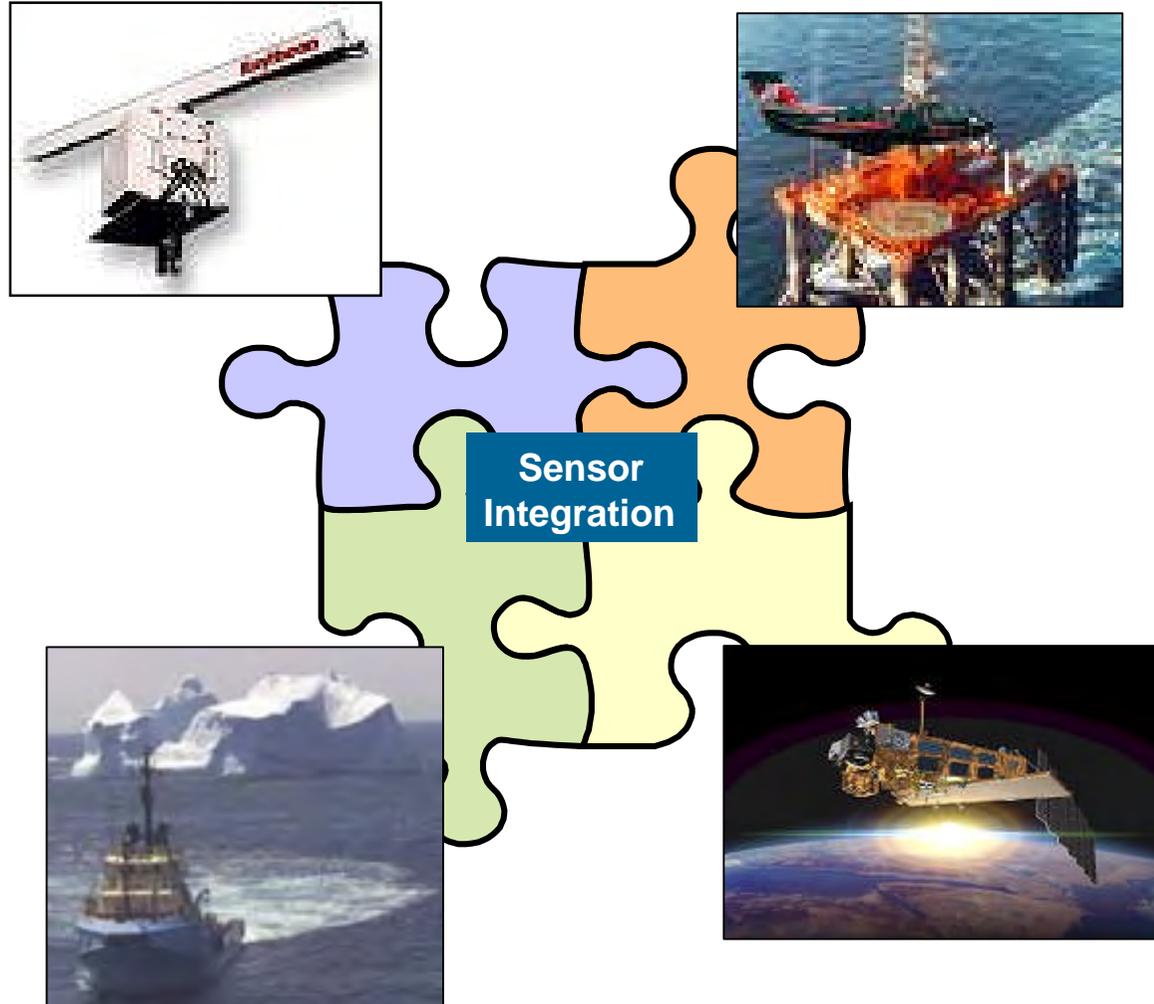


Ice Management



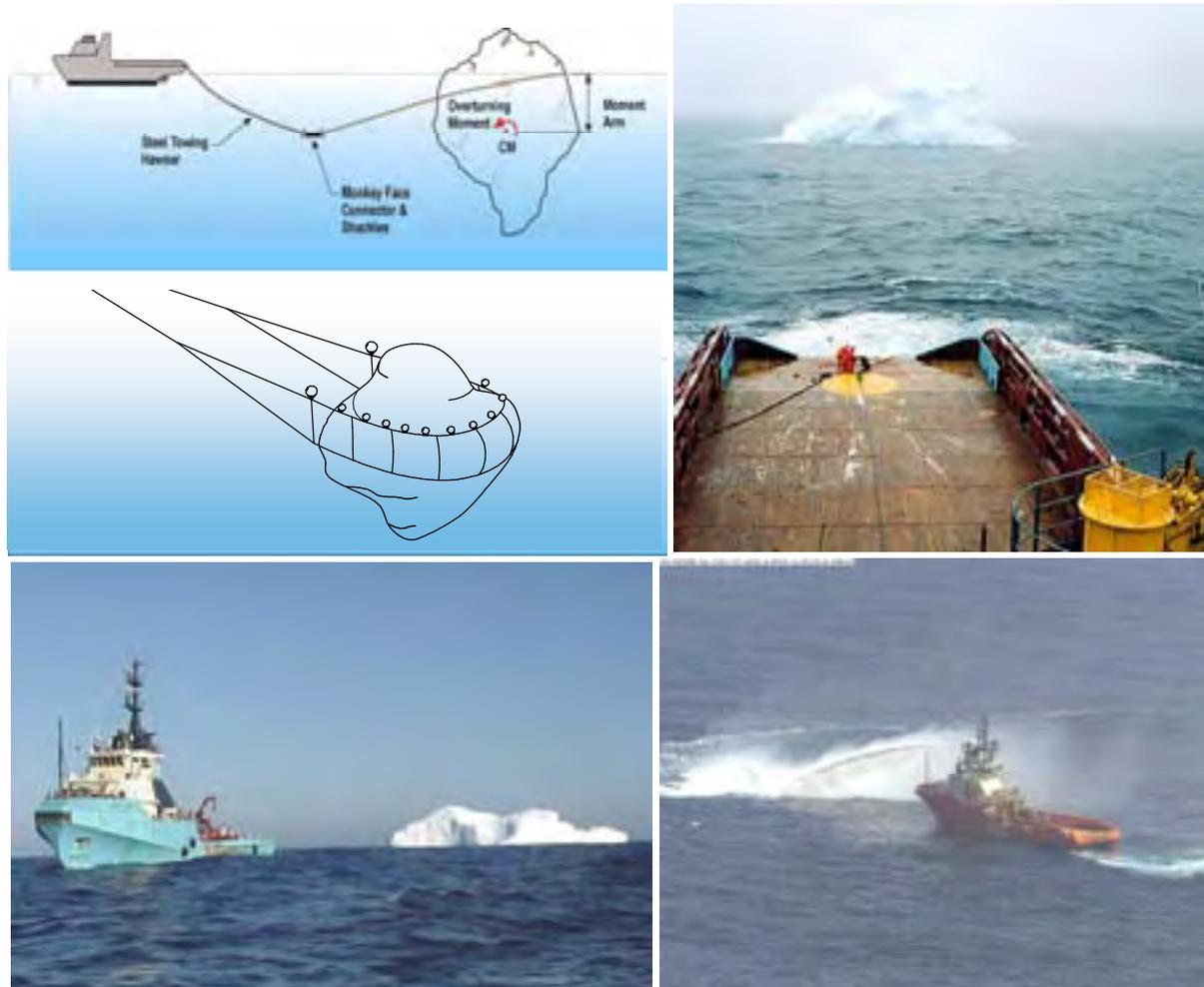
Ice Management



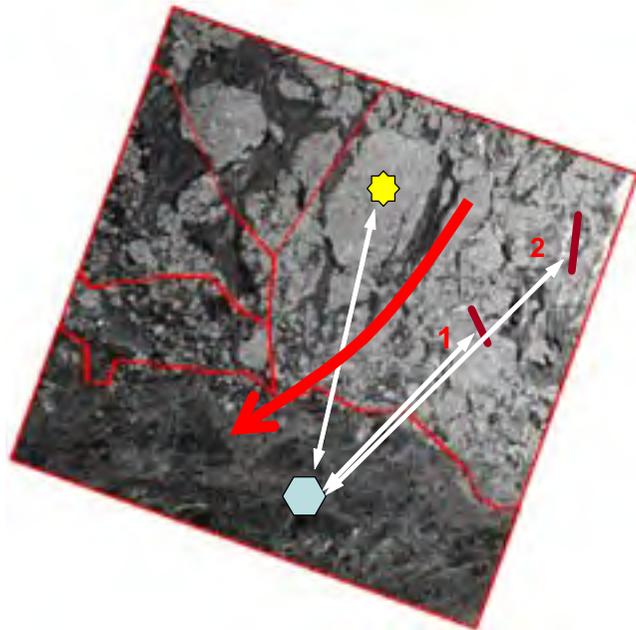
- Detection
 - Marine Radar
 - Satellite Radar
 - HF Radar
 - Aerial & Vessel Reconnaissance
 - Detections vary in space and time
 - DATA FUSION

Ice Management

- Physical Management
 - Towing, water cannon, towing catenary



Ice Management



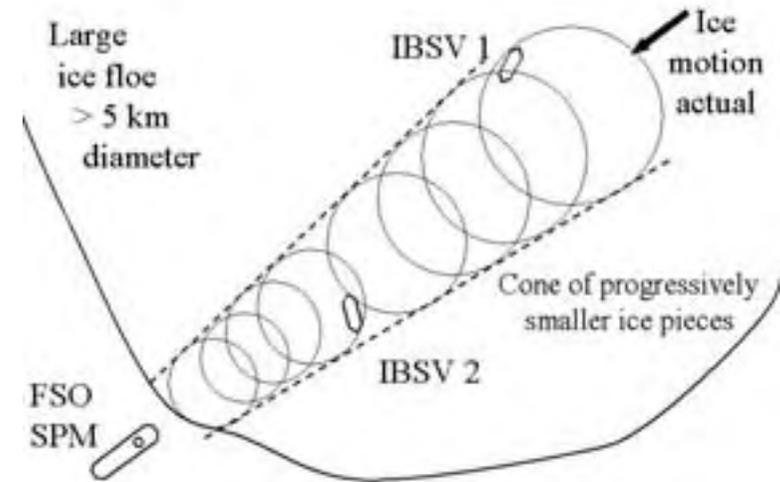
Ice Condition Analysis

☀ floe 5 km diameter
25 km distance

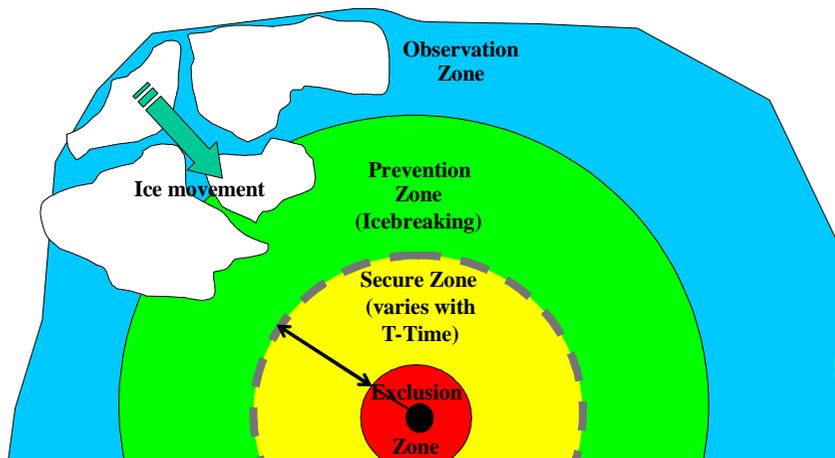
1 - ridge
1500m length
15 km range

2 - ridge
2000m length
30 km distance

➔ - forecasted drift



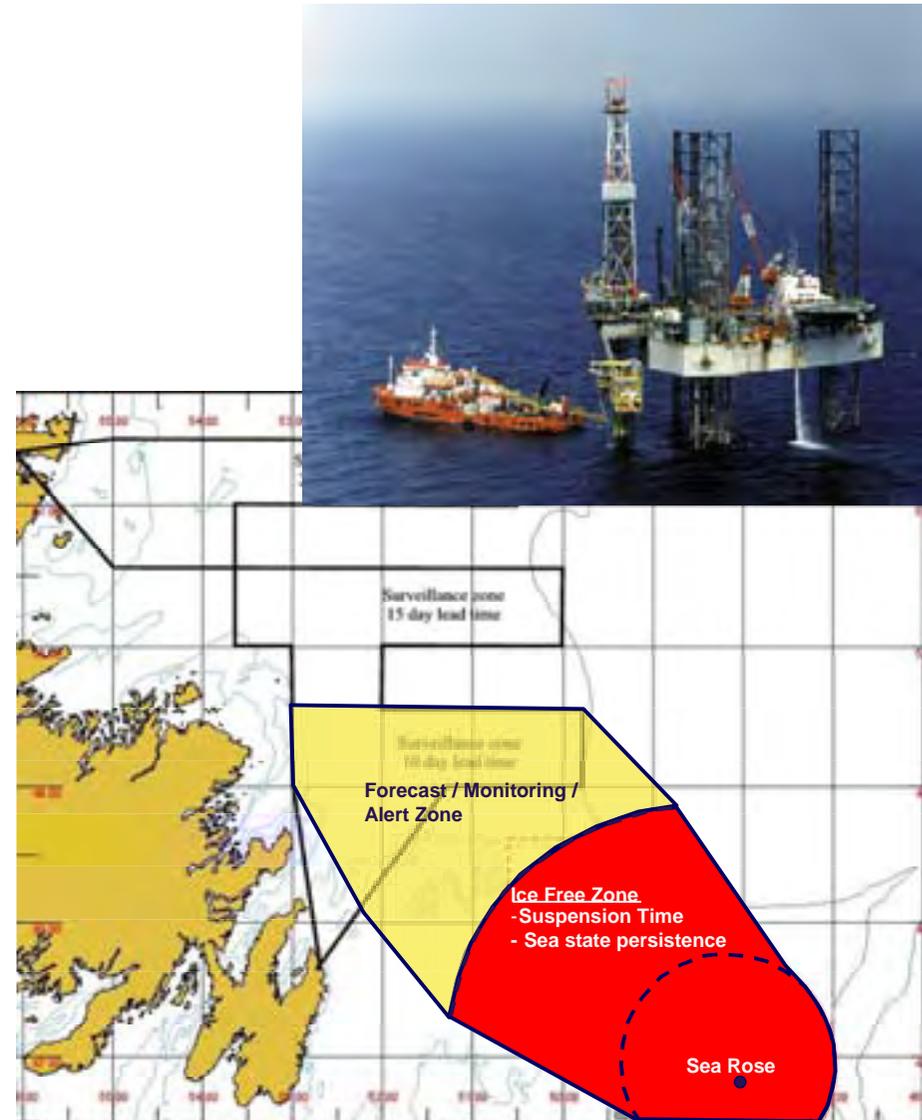
CONE PATTERN - 2 SHIPS



Hazard Response Time (HRT)	> 24 hrs	24 to 12 hrs	12 to 6 hrs	6 – 1 hour	< 1 hour
Unmanageable Hazard	GREEN	YELLOW	ORANGE	RED	Brown
Hazard Manageable with 1 IBSVs	GREEN	GREEN	YELLOW	ORANGE	RED
Hazard Manageable with 2 IBSV	GREEN	GREEN	GREEN	YELLOW	ORANGE

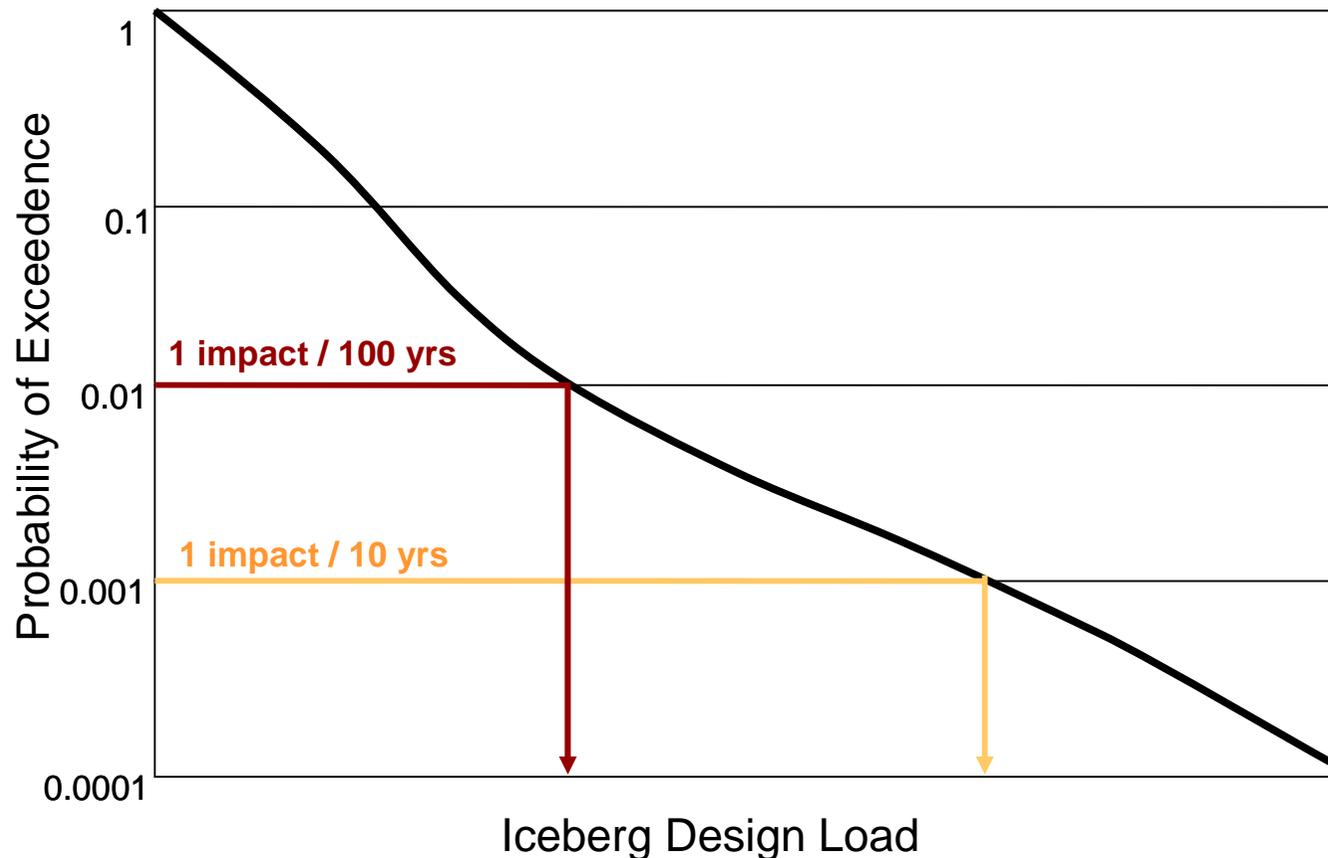
Jack-ups on Grand Banks

- Seasonal ice occurrence
- Analysis of risk
- T-Time
 - Suspend operations and move
- Zone size
 - Ice free
 - Evacuation
 - Sea state persistence
- Basis for safe operation



Risk Mitigation - Design Loads

- Global Loads (10^{-4} exceedence)
- Reduced risk ... reduced load
 - The longer you fish ... the bigger fish you will catch.



Facility Considerations

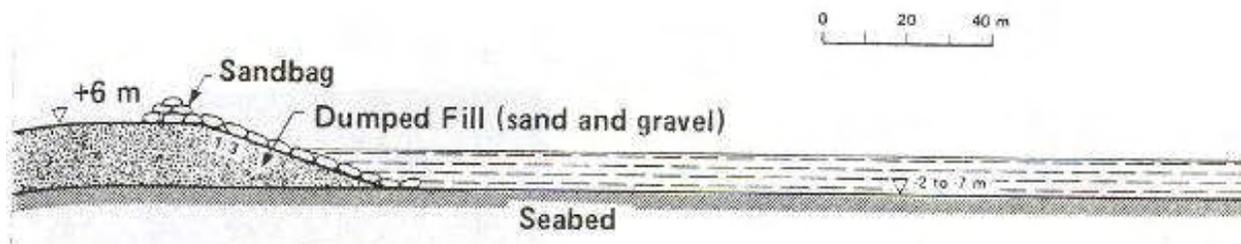
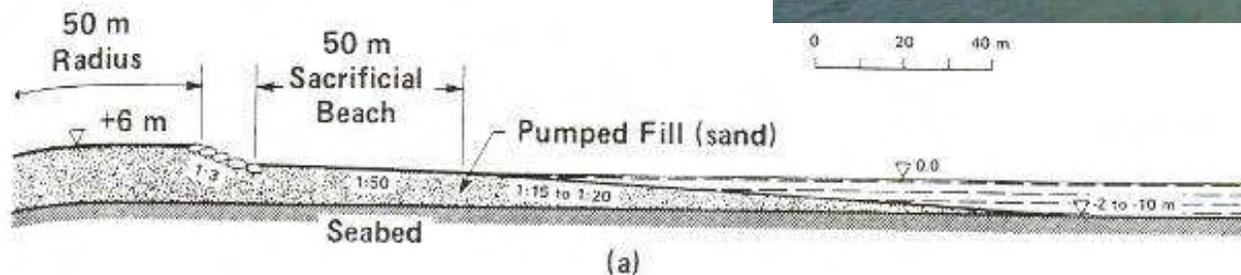
Influence of environment on
structure type

Drilling / Production Structural Considerations

- Ice movement
- Ice loads
 - Lateral sliding resistance ... but wider .. the higher the load
 - Overturning moment
 - Structural integrity
- Ice erosion
- Wave erosion
- Wave loads

Selection of Structure

- Conditions
 - Shallow Water 0-10m
 - Landfast Ice
- Structure
 - Gravel Island



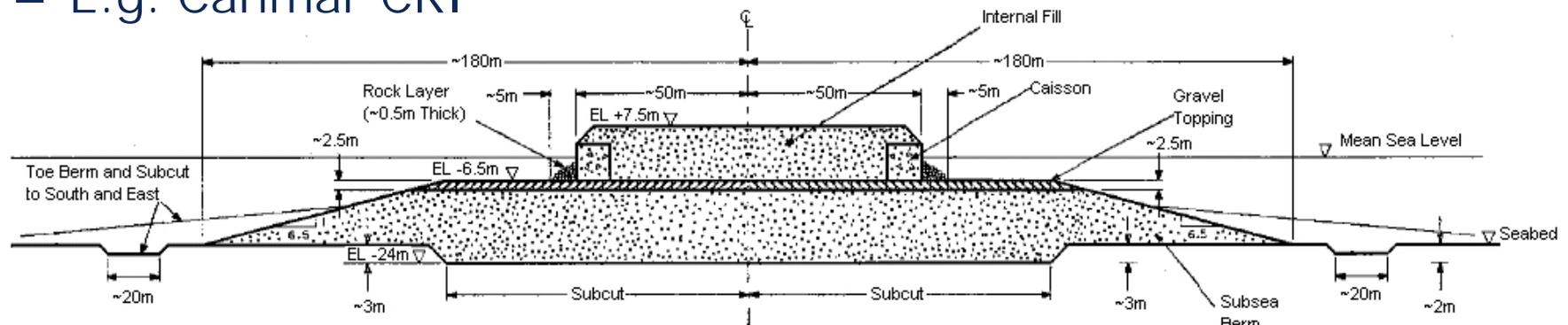
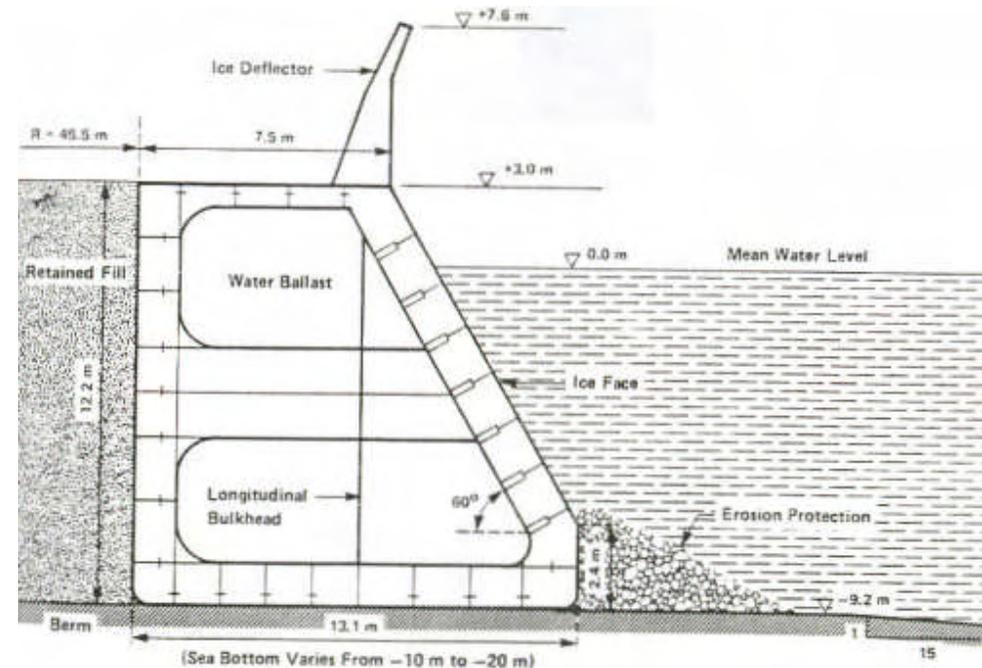
Selection of Structure

- Conditions
 - Shallow Water 0-10m
 - Light to mod ice conditions (1st year & multi-year floes and ridges)
 - Ice force < 500MN
- Structure
 - Spray Ice Island



Selection of Structure

- Conditions
 - Moderate water 15-35m
 - Moderate ice condition (1st year & multi year ice and ridges)
 - Ice force < 560MN
- Structure
 - Caisson Retained Islands
 - Steel or Concrete
 - E.g. Canmar CRI

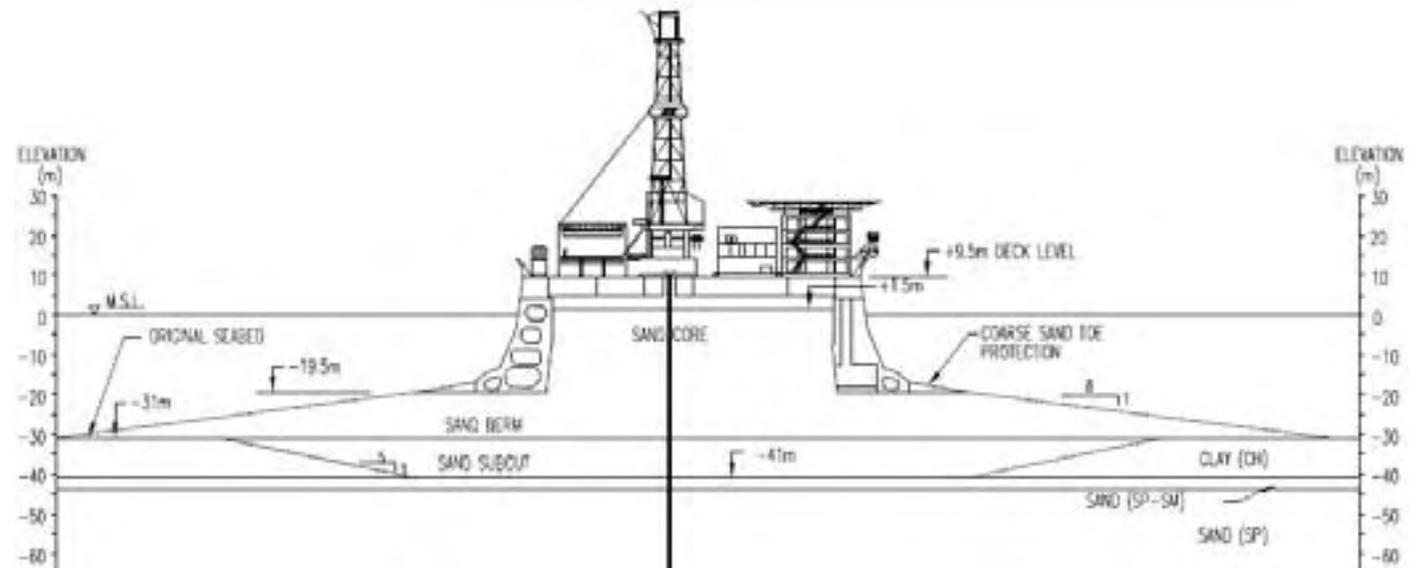


Selection of Structure

- Conditions
 - Moderate to Deep Water 15-50m
 - Heavy ice conditions (1st year multi-year level ice and ridges)
 - Ice force ~ 750MN



- Structure
 - GBS
 - Gulf Molikpaq
 - mobile



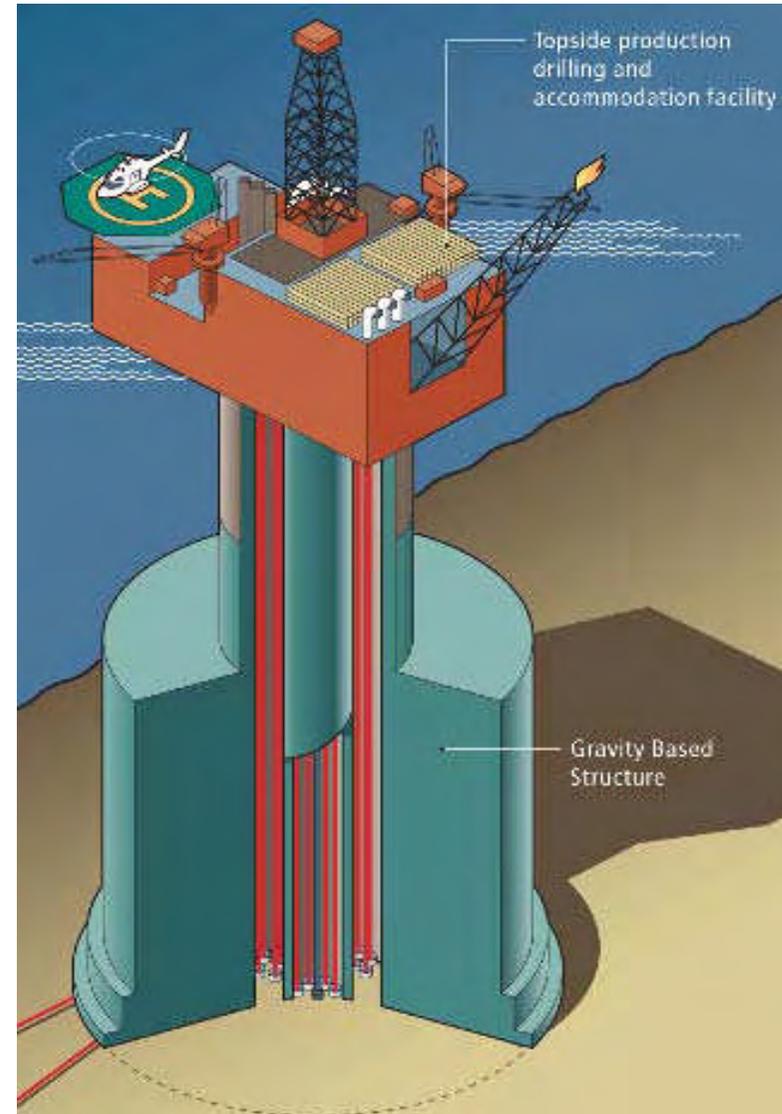
Selection of Structure

- Conditions
 - Mod to deep Water
15-50m
 - Deeper water with berm
 - Light to mod ice
(1st year level and
ridged ice)
 - Year round operations
- Structure
 - GBS
 - Lunskeye (Lun-A)
platform



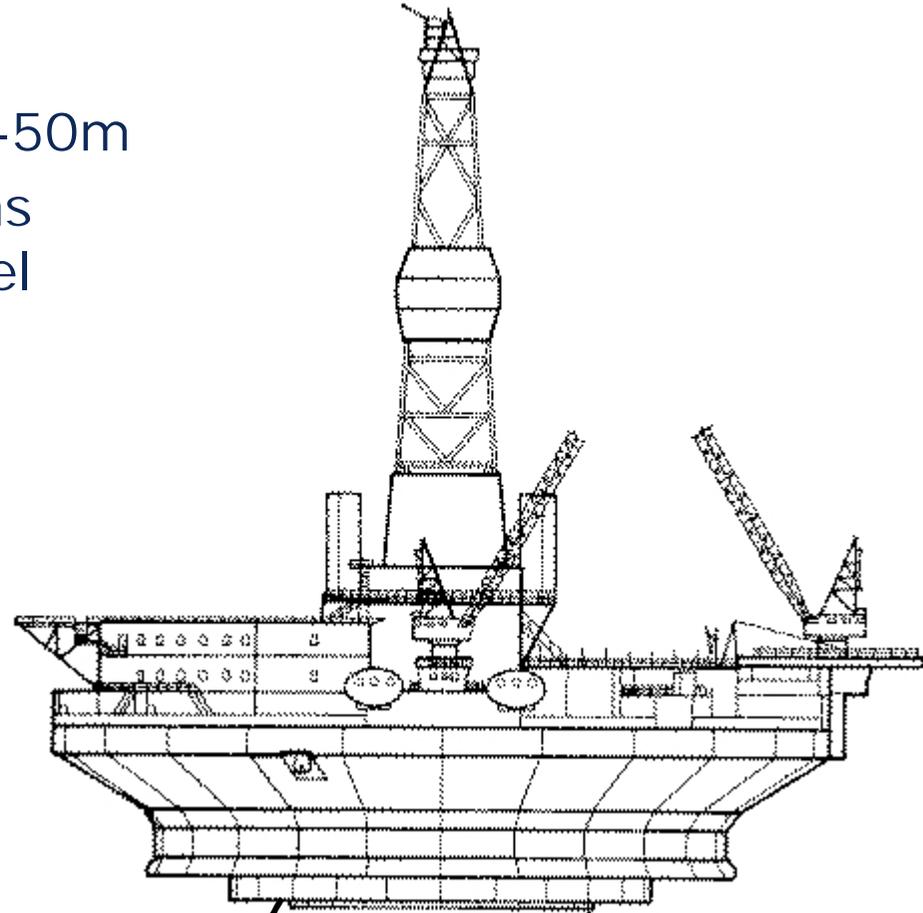
Selection of Structure

- Conditions
 - Water Depth 50 - 100m
 - Moderate ice conditions
 - Load < 1000MN
 - Rare iceberg loads
 - If open water, wave loads may dominate
- Structure
 - Conventional GBS



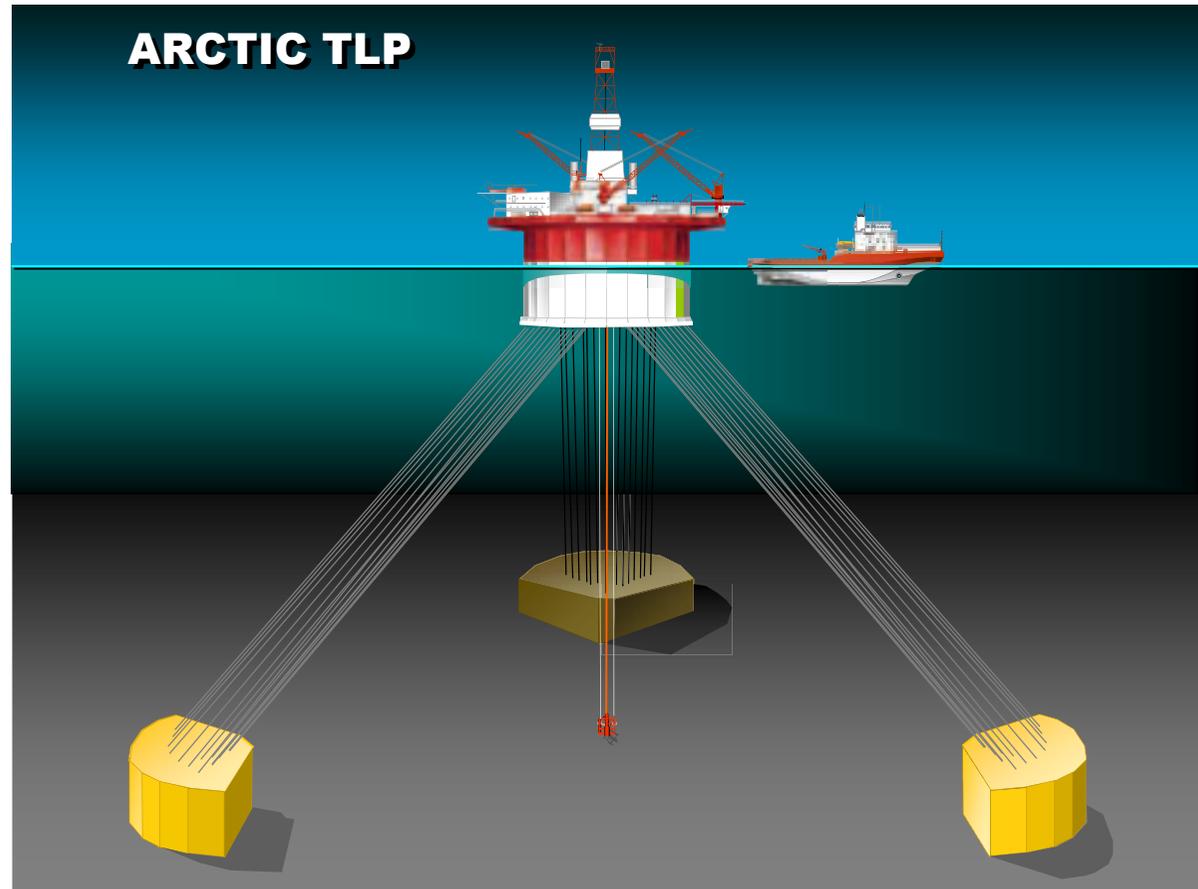
Selection of Structure

- Conditions
 - Moderate water depth 22-50m
 - Light to mod ice conditions (1st year & multi-year level ice and ridges)
 - Low waves
 - Seasonal operations
- Structure
 - Mobile
 - Moored floating structure
 - Extended season with management
 - E.g. Kulluk



Selection of Structure

- Conditions
 - Deepwater
 - Heavy ice
 - Year round operations
- Structure
 - mobile
 - Moored floater

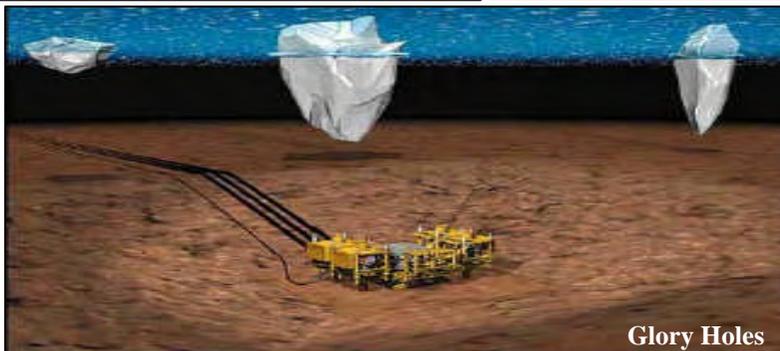


Selection of Structure

- Conditions
 - Mobile unit
 - Deepwater 100 - 250m
 - Light ice conditions
 - Seasonal Operation
- Structure
 - Moored floating structure
 - Ice classed vessel
 - Extended season with management
 - E.g. Canmar Explorer III



Grand Banks Developments



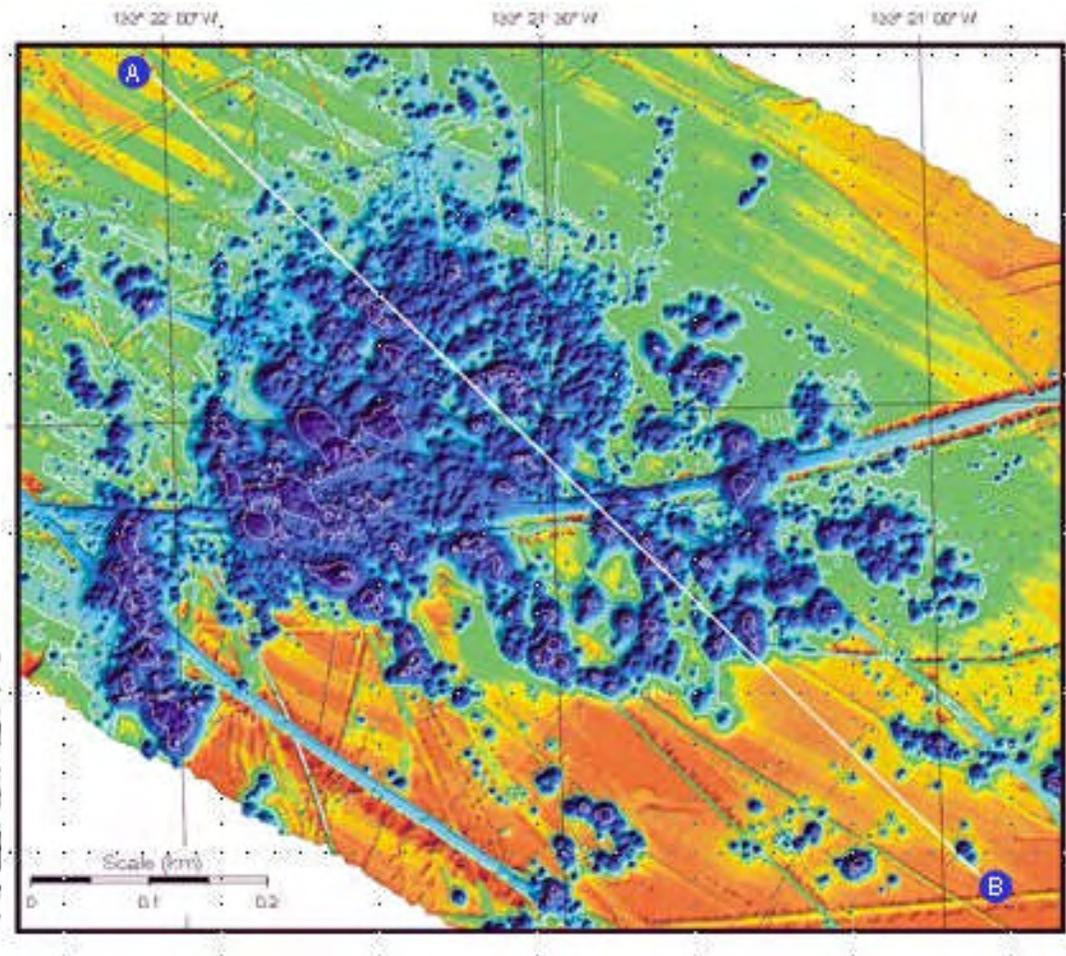
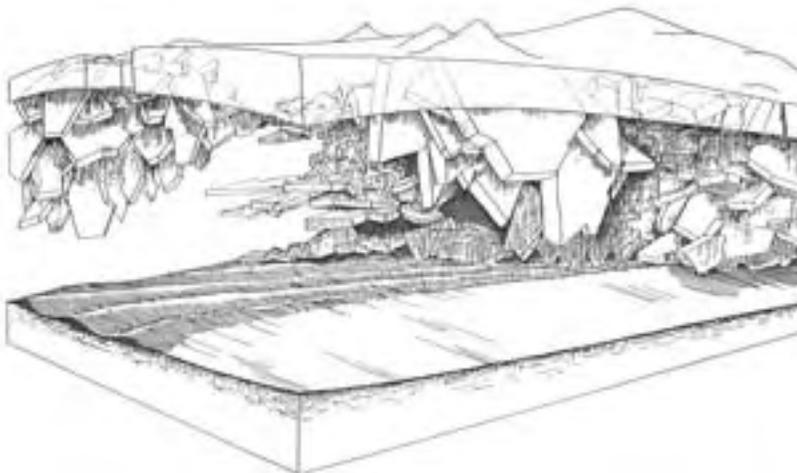
- Challenges
 - Sea ice and iceberg risk
 - Geotechnical properties
- Facility Types
 - GBS, FPSO, Subsea
- Special Design Features
 - Structural Reinforced
 - Disconnection
 - Gloryhole
- Risk Mitigation
 - Iceberg detection and towing
 - Alert zones
 - Glory Holes
 - Pipeline trenching

Ice Gouging

Subsea pipeline protection

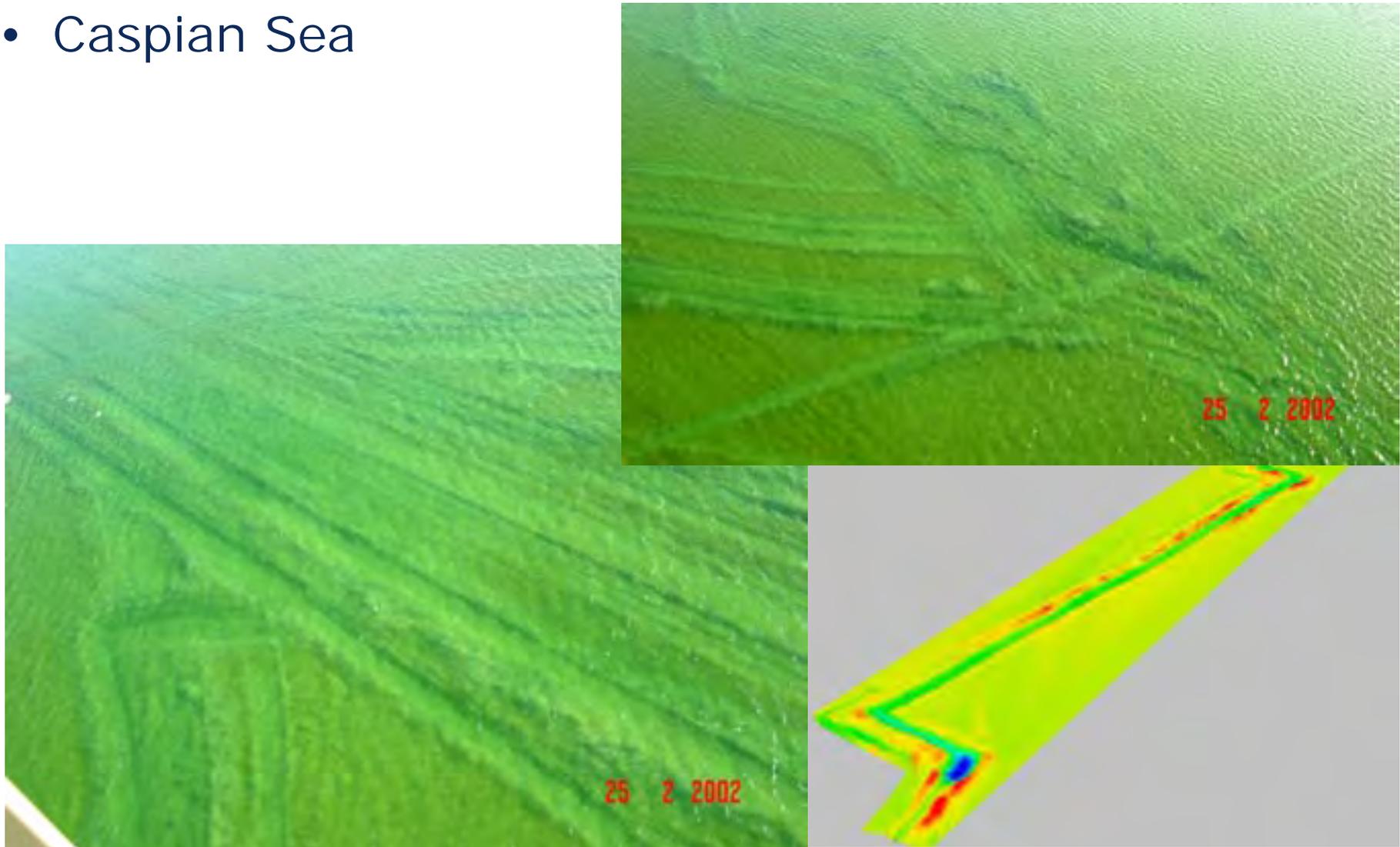
Ice Gouge

- Protection
 - Pipeline burial depth
 - Gloryhole for subsea equip
- Ice gouge parameters
 - Gouge dimensions
 - Recurrence rate
 - Gouge infill
- Route selection
 - Hazard maps

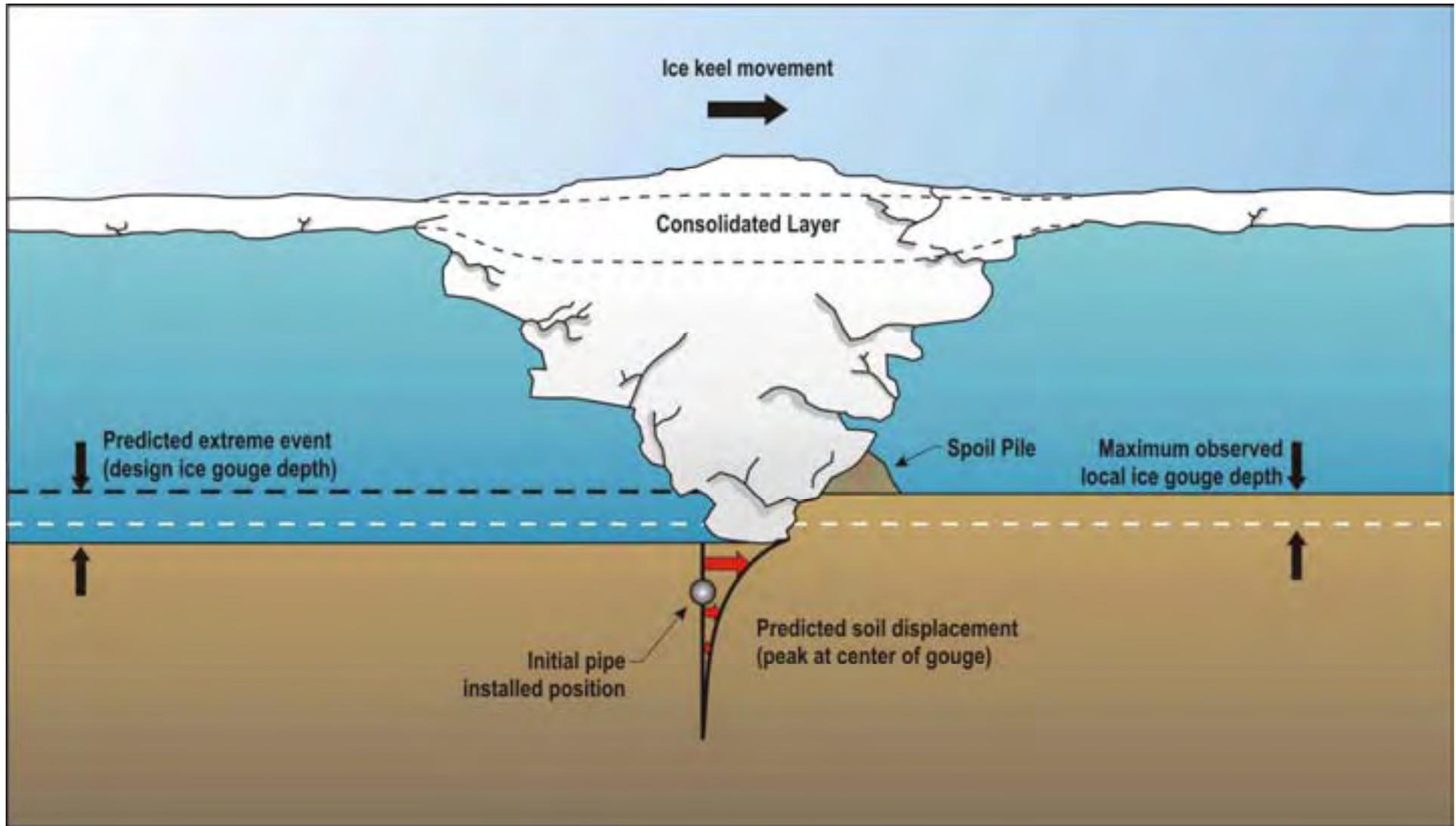


Ice Gouge

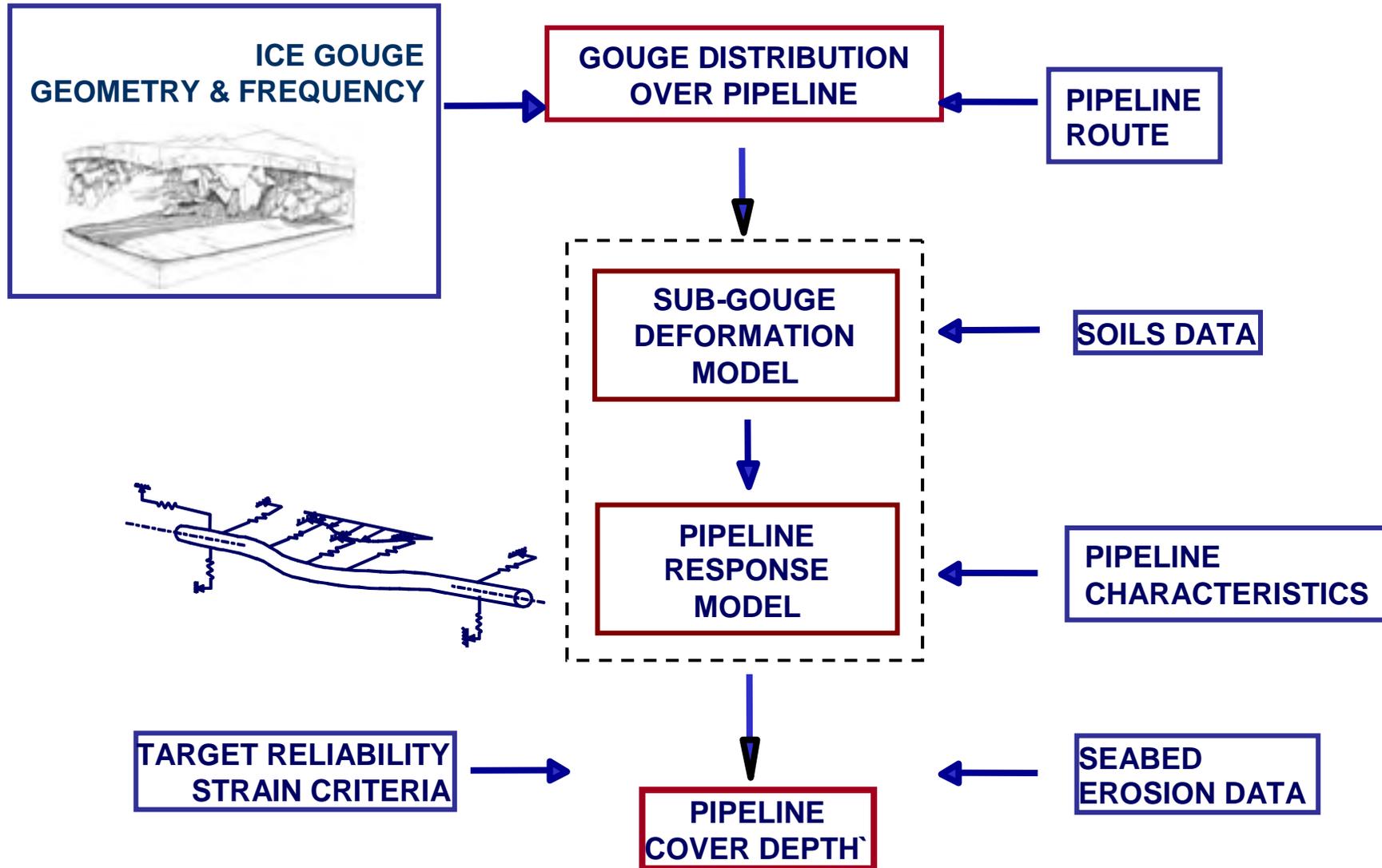
- Caspian Sea



Ice Gouge

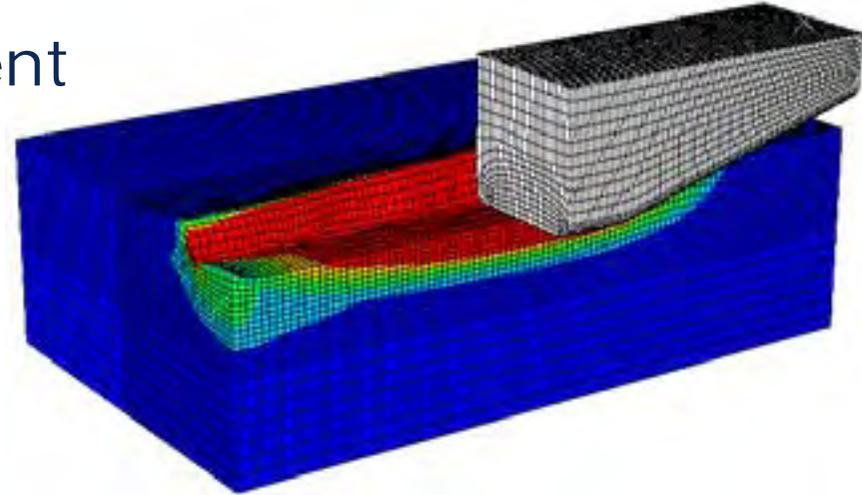


Design Methodology

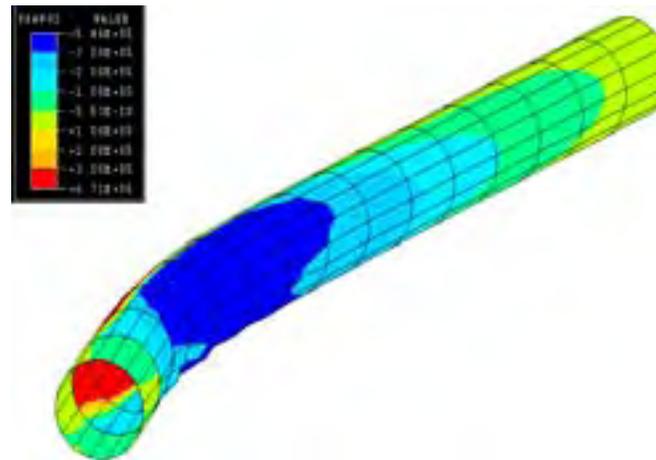


Ice Keel/Soil/Pipe Response Model

- Subgouge soil displacement
 - Keel geometry
 - Keel strength
 - Soil strength



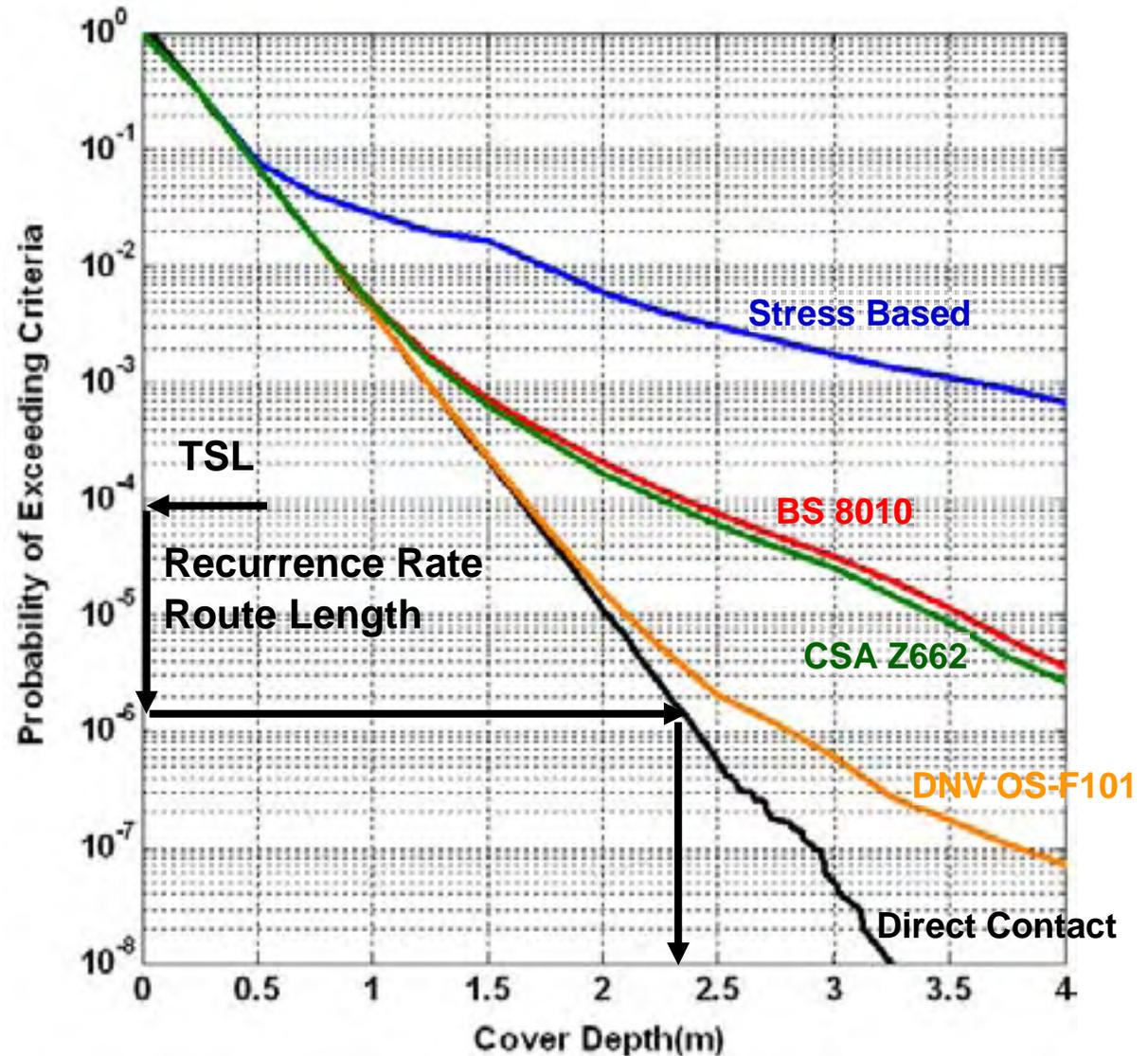
- Pipeline response
 - Large deformation
 - Strain



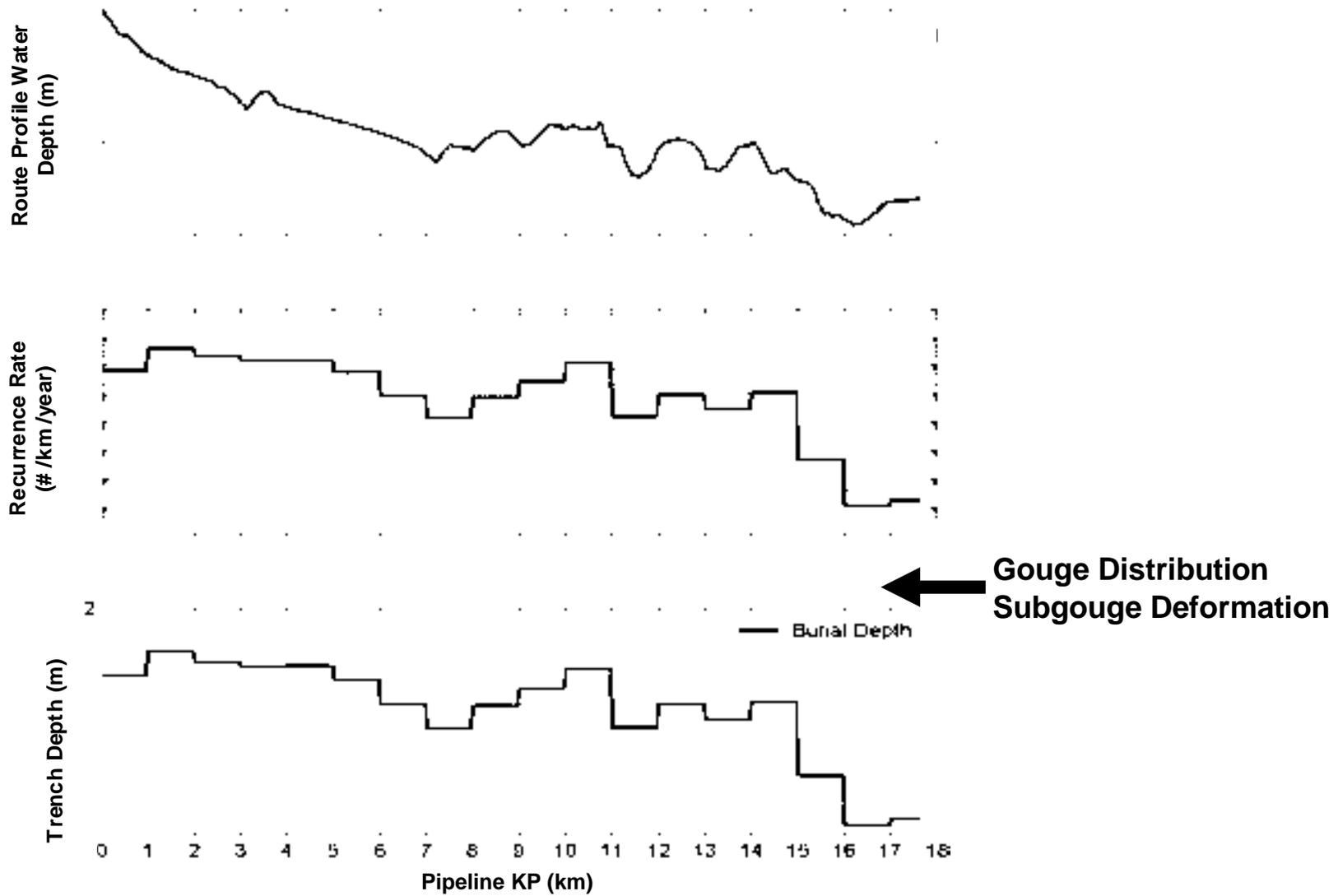
Probabilistic Design

Burial Depth

- Design Approach
- Pipeline specification
 - D/t
 - Internal press
 - Straining hardening
 - Pipe grade
 - Weld parameter
- Strain limits



Typical Analysis Result



The End

