Appendix M4

Geotechnical Risk Register

Geotechnical Risk Register

May, 2010

Introduction

A Geotechnical Risk Register has been compiled to show the degree of risk attached to various elements of the proposed pipeline construction and operation on a qualitative scale based on Clayton (2001)[1]. The purpose of the register is to provide and outline a description of the hazards, identify the likely cause, describe the potential impact of the hazard and identify the design and construction controls to be implemented in order to minimise the geotechnical risk.

The Geotechnical Risk Register will be actively used during the design and construction stage of the project as a guide to address geotechnical issues. The risk register will be up-dated to reflect additional data and experience as it is gained.

Whilst probability of a hazard occurring can be reduced to a minimum by geotechnical design, the impact cannot be reduced below very low. The probability and impact of a hazard have been judged on a qualitative scale as set out in Table 1.

PROBABILITY (P)		IMPACT (I)	
Description	**Score**	**Description**	**Score**
Very likely	5	Very high	5
Probable	4	High	4
Likely	3	Medium	3
Possible	2	Low	2
Negligible	1	Very low	1
Not applicable	0	-	-

Table 1 Factors used to Compile Risk Matrix

The list of hazards identified in this Geotechnical Risk Register is non-exhaustive and has been selected based on specific critical hazards that are relevant to this scheme having regard to health & safety, environmental, programme and cost considerations. However, it must be noted that this document is a Geotechnical Risk Register. It is not a Health and Safety or Environmental Risk Register. The degree of risk is determined by combining the probability and impact assessments: Risk (R) = Probability (P) x Impact (I). The the severity of the risk is as set out in Table 2.

IMPACT \ PROBABILITY	**1**	**2**	**3**	**4**	**5**
5	5	10	15	20	25
4	4	8	12	16	20
3	3	6	9	12	15
2	2	4	6	8	10
1	1	2	3	4	5

Key:

	Unacceptable
	Early attention
	At least regular attention

Table 2 Risk (R) Matrix

Geotechnical Risk Categories:

Pipe Construction on Land
Tunnelling
Temporary Works
In Operation

References

[1] Clayton, C.R.I., (2001). Managing Geotechnical Risk. Thomas Telford, London.

Corrib Onshore Pipeline

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Notes:

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3 The register is a live document that will be up-dated as the project develops to reflect additional data and experience.
4 The risk rating values given in the register are based on engineering judgment and as such may vary between individuals depending on the perception of risk.
5 Some of the hazards identified would be geotechnical concerns but may also include environmental and pipeline design concerns.
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7 Causes, potential impacts, risk control measures or contingency measures listed may not be numbered in order of preference.

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No.	Hazard	Cause	Potential Impact		Risk Rating (Refer Table 12.1 and 12.2)			Risk Control Measure (RCM)		Risk Rating following RCM (Refer Table 12.1 and 12.2)			Contingency Measures
			Category	Specific	P	I	R	Design Control	Construction / Operations Control	P	I	R	
Pipeline Construction on Land													
1	**Liquefaction of base of pipeline trench** **Sand / subsoil mixing with water and forming liquid material.**	1. High/rising tidal waters causing liquefaction (quick conditions) of sand in excavation base 2. Inadequate site investigation information 3. Inadequate design and understanding of ground conditions 4. Improper construction	1. Health & Safety 2. Programme 3. Cost	1. Risk of death or injury by drowning 2. Damage to plant 3. Loss and cessation of works	2	3	6	1. Review of previous excavations in the locality and in similar ground 2. Detailed site investigation to include trial trenches to expose soils 3. Boreholes and trial pits to be taken below base of pipeline trench 4. Specify method statement from the Contractor for working in tidal sands and check that he is fully cognisant with ground conditions 5. Check of implications of over-excavation 6. Check requirement to have ballast stone available to place in base of trench	1. Site supervision staff to inspect trench daily 2. No/limited access into trench 3. Areas of unexpectedly deep and weak ground to be reported and await further instruction 4. Works sequenced to tides and weathered conditions 5. Supervision to ensure construction carried out as detailed in the method statement 6. Limited exposure of trench base to avoid potential for base (liquefaction) failure	1	3	3	1. Stop works 2. Ballast stone to be placed in base of excavation 3. Ensure localised area made stable
2	**Escape of potential contaminated water from works into surface water channels** **Possible contaminants from leakages, spills or fines/suspended solids**	1. Extended periods of wet weather and under-design of temporary pumping 2. Over-pumping of excavation into surface water channel. 3. Potential contamination from run-off from works 4. Potential contamination from backfill material	1. Environmental	1. Risk of contamination of surface water	3	4	12	1. Walk-over survey to identify areas where greater risk of water entering works and becoming contaminated 2. Detailed site investigation to include trial trenches to expose soils and monitoring of groundwater along route 3. Spillages from plant - addressed in environmental impact statement 4. Consider limiting the extent of works/trench opened in sensitive areas 5. Specify method statement from contractor that clearly demonstrates their awareness of this issue 6. Identify any sensitive receivers along route	1. Supervision staff to be fully briefed on the ground conditions, design requirements and construction methodology 2. Supervising staff aware of weather forecasts 3. Appropriate pumping facilities to be put in place during the construction phase and silt traps/bunds constructed 4. Temporary bunds and drains to be installed as appropriate 5. Supervision to ensure construction carried out as detailed in the method statement 6. Measures to prevent contamination/clean up contamination before work continues	1	4	4	1. Stop work 2. Environmental Manager to be notified immediately. 3. Establish if contamination includes oil / diesel 4. Identify source of contamination and solve problem immediately as per EMP. 5. Oil contaminated water to be treated prior to discharge (use oil interceptors if appropriate) 6. Excess water to be diverted into drainage channels with filtration / sedimentation as required 7. Use simple and effective filtration measures to remove particle load e.g. straw bales/terram in drainage channels 8. Sedimentation tanks to be used (and cascaded if necessary) 9. Use adjacent areas within temporary working area as natural filter in agreement with NPWS e.g. for high levels of suspended peat 10. Reserve / additional pumping facilities to be available
3	**Unexpected hard obstructions in excavations, e.g. boulders, rock outcrops**	1. Ground conditions differing from those indicated from site investigation 2. Inadequate site investigation information	1. Programme 2. Cost	1. Delays to works 2. Increased noise levels due to additional rock breaking requirements	4	2	8	1. Carry out extensive site investigation. 2. Walk-over survey of route to identify areas of variable ground (e.g. shallow rock, till, peat/organic clay) 3. Selection of conservative design parameters to allow for variable conditions on site 4. Require detailed construction method statement that clearly demonstrates understanding of the ground conditions and risks involved 5. Monitoring and observation method proposed as part of construction controls	1. Construction personnel briefed on expected ground conditions 2. Reporting by site staff on change in ground conditions from that predicted 3. Advance notice of change in predicted ground condition to be fed to designers 4. Supervision to ensure construction carried out as detailed in the method statement	1	2	2	1. Stop works 2. Area to be assessed 3. Use rock breakers/non-explosive pre-splitting of rock using expansive grouts or similar
4	**Open excavations and holes filled with disturbed peat**	1. Excavation works 2. Displacements and slides 3. Improper construction methods	1. Health & Safety 2. Environmental 3. Programme 4. Cost	1. Risk of death or injury from falling into excavation 2. Damage to plant	3	5	15	1. Carry out extensive site investigation 2. Walkover survey of route to identify areas of variable ground (e.g. shallow rock, till, peat/organic clay) 3. Detailed method statement to be prepared with respect to excavation	1. Appropriate sequencing of works 2. Supervision of works by suitably qualified person 3. Tool box talks to be carried out prior to works 4. Ensure no excavations left open or unprotected 5. Backfill to be with a suitable material 6. Supervision to ensure construction carried out as detailed in the method statement	2	3	6	1. Stop work 2. Backfill open excavations with stone 3. Over excavate disturbed peat localised area and backfill with stone
5	**Unexpected soft ground in pipeline trench (outside of peat areas)**	1. Ground conditions differing from those indicated from site investigation 2. Inadequate site investigation information	1. Programme 2. Cost	1. Delays to works 2. Increased excavation and backfilling requirement	4	3	12	1. Carry out extensive site investigation. 2. Walk-over survey of route to identify areas of variable ground (e.g. shallow rock, till, peat/organic clay) 3. Selection of conservative design parameters to allow for variable conditions on site 4. Detailed method statement to be prepared 5. Monitoring and observation method proposed as part of construction controls	1. Construction personnel briefed on expected ground conditions 2. Reporting by site staff on change in ground conditions from that predicted 3. Record of change in predicted ground condition to designers 4. Supervision to ensure construction carried out as detailed in the method statement	1	3	3	1. Stop work 2. Where appropriate over excavate and backfill with stone 3. Place stone ballast to secure base of excavation
6	**Uncontrolled localised peat displacement**	1. Unexpected weak ground conditions. 2. Intense rainfall event 3. Improper construction 4. Heave of adjacent areas due to compaction of backfill	1. Health & Safety 2. Environmental 3. Programme 4. Cost	1. Risk injury 2. Environmental damage 3. Damage to plant 4. Loss and cessation of works 5. Damage to adjacent property	2	4	8	1. Carry out detailed site investigation 2. Walk-over survey of route to identify areas of potential failure 3. Obtain good understanding of stability of site and possible mechanism that might trigger ground movement 4. Assessment of potential for peat displacement 5. Design conservatively to eliminate all mechanisms likely to trigger movement 6. Detailed method statement to be prepared 7. All personnel to be fully cognisant with ground conditions expected 8. Provide sheet piling and shear keys as potential mitigation measures	1. Site supervision staff fully briefed on ground conditions 2. Provision and monitoring of instrumentation to record ground movement 3. Ensure control of all construction practices so that all works on site are within design conditions 4. Ongoing site inspection of site for evidence of ground movements 5. Have sheet piles and piling rig readily available. (refer to piling risks) 6. Divert streams and surface water away from problematic area 7. Provide suitably qualified person to monitor works	1	4	4	1. Stop works 2. Install sheet piling to prevent ground movement using appropriate machinery 3. Monitor movements following installation of sheetpiles until movements have ceased 4. Reduce speed of works 5. Reduce excavation lengths prior to backfilling with stone 6. Install sheet piling ahead of works if possible as additional preventative measure

Corrib Onshore Pipeline

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			Category	Specific	P	I	R	Design Control	Construction / Operations Control	P	I	R	
7	**Plant toppling or coming off access road/bog mats**	1. Local softer/weaker pockets below road 2. Excessive eccentric loading on supporting road/soft ground including transportation of materials	1. Health & Safety 2. Programme 3. Cost	1. Risk of death or injury by fall/crushing plant 2. Damage to plant 3. Loss and cessation of works 4. Localised displacement of peat/ground	3	5	15	1. Carry out detailed site investigation along the route of the access roads to determine variability of the peat/soft ground strengths 2. Walk-over survey of route to identify areas of potential softer ground 3. Design temporary access roads/bog mats based on good working practice within the industry – e.g. proven practices within Bord na Mona 4. Allow for eccentric loading and additional width and passing and turning areas 5. Use conservative design parameters for ground 6. Detailed method statement to be prepared	1. Supervising staff and construction staff to be fully briefed on particular loading limitations and construction methodology 2. Supervision to ensure that the plant movement/loading is carried out as detailed in the method statement 3. Comprehensive and regular monitoring of road/bog mats and suitable markings showing edge of road 4. Installation of non-peat loading supported roads where appropriate	1	5	5	1. Stop works 2. Stabilise side slopes 3. Increase width of access roads where feasible 4. Use piled access roads
8	**Instability of peat arisings / turves due to failure of underlying ground**	1. Unexpected soft ground conditions 2. Over-loading of under-lying ground/peat	1. Health & Safety 2. Environmental 3. Programme 4. Cost	1. Risk of injury by collapse arisings 2. Damage to plant 3. Neighbouring ground affected 4. Loss and cessation of works	3	4	12	1. Carry out detailed site investigation along the route to determine variability of the peat/soft ground strengths 2. Walk-over survey of route to identify areas of potential softer ground 3. Use conservative design parameters for ground and peat 4. Specify areas where arisings can be placed and limits on arisings height 5. Detailed construction method statement to be prepared	1. Supervising staff and construction staff to be fully briefed on particular loading limitations and construction methodology for arisings 2. Employment of contractor/personnel familiar with soft ground conditions 3. Supervision to ensure that arisings placed as per method statement including a experienced geotech eng. 4. Comprehensive and regular monitoring of arisings 5. Supervision to ensure construction carried out as detailed in the method statement	1	4	4	1. Stop works 2. Use bog mats under arisings 3. Reduce height of arisings 4. Surplus arisings to be removed to another location 5. Local surplus of peat for backfilling to be stored in adjacent / nearby areas of the temporary working area
9	**Instability of peat arisings / turves due to excessive rainfall/run-off**	1. Excessive rainfall 2. Overly softened arisings 3. Concentration of water due to construction activities	1. Health & Safety 2. Environmental 3. Programme 4. Cost	1. Risk of injury by collapse arisings 2. Damage to plant 3. Neighbouring ground affected due to run-out and run-off into water courses 4. Loss and cessation of works	3	3	9	1. Carry out detailed site investigation along the route to determine variability of the peat/soft ground strengths 2. Walk-over survey of route to identify areas of potential softer ground 3. Use conservative design parameters for ground 4. Specify areas where arisings can be placed and limits on arisings height and geometry depending on condition of arisings 5. Shaping of arisings to shed water and placement of arisings away from any surface water sources and provide control to runoff. 6. Detailed construction method statement to be prepared	1. Supervising staff and construction staff to be fully briefed on particular loading limitations and construction methodology for arisings 2. Employment of contractor/personnel familiar with soft ground conditions 3. Supervision to ensure that arisings placed as per method statement 4. Inspection after any significant rainfall event 5. Preparation of areas if significant rainfall forecasted 6. Comprehensive and regular monitoring of arisings 7. Drainage ditches and watercourses to be maintained.	1	3	3	1. Stop works 2. Reserve pumping facilities to be available 3. Revise drainage design 4. Reduce height of arisings
10	**Working in areas of soft ground/peat**	1. Unexpected soft ground conditions 2. Upper strong vegetated layer in peat has been broken 3. Plant too heavy 4. Existence of bog-holes 5. Excessive water logging due to rainfall	1. Health & Safety 2. Programme 3. Cost	1. Plant sinking or bogging in ground 2. Personnel falling into bogholes/soft ground areas. 3. Access for plant/personnel not possible 4. Loss and cessation of works	5	3	15	1. Detailed site investigation to include trial trenches to expose soils 2. Boreholes and trial pits to be taken at least below base of excavations/pipeline trench 3. Walkover, survey and map route to identify soft ground areas, bogholes, swallowholes, springs, streams (surface and subterrain) 4. Specify use of bogmats 5. Create safe working platforms (stone road) 6. Specify use of low pressure bearing machinery	1. Site supervision staff fully briefed on ground conditions. Geotechnial Engineer present. 2. Thorough induction of all personnel on working in soft ground with followup toolbox talks. 3. Employment of contractor/personnel familiar with soft ground conditions. 4. Site walkover at start of each day to inspect ground conditions and to alert construction personnel to ‘ potential risk’ areas 5. Cordon-off of areas of weak/ soft ground that pose an unacceptable risk	2	3	6	1. Stop work 2. Assess situation 3. Deploy engineering solution to prevent ground movement 4. Monitor situation 5. Use additional stone to provide firm surface. Bogmats to be available also
11	**Flooding due to rainfall/surface water inflow into excavation**	1. Extended periods of wet weather 2. Reduced capacity of temporary pumping	1. Health & Safety 2. Environmental 3. Programme 4. Cost	1. Risk of death or injury by drowning 2. Risk of death or injury by collapse of trench side wall 3. Damage to plant 4. Excessive run-off into surface watercourses 5. Loss and cessation of works	3	5	15	1. Plan/program for high rainfall events 2. Use conservative design parameters for the design storm event 3. Detailed method statement to be prepared with respect to dewatering and protection of works	1. Supervising staff aware of weather forecasts 2. No/Restricted access into excavation 3. Pumping facilities to be put in place during the construction phase 4. Temporary bunds and drains to be installed where appropriate 5. Ensure construction carried out as detailed in the method statement 6. Agree unacceptable work conditions and/or temporarycessation of the work	2	5	10	1. Stop work 2. Assess situation 3. Deploy engineering solution to dewater 4. Monitor situation 5. Reserve / additional pumping facilities to be available
12	**Flooding due to groundwater inflow into excavation**	1. Extended periods of wet weather leading to build-up in groundwater 2. Interception of water-bearing soils 3. Unexpected ground conditions	1. Health & Safety 2. Environmental 3. Programme 4. Cost	1. Risk of death or injury by drowning 2. Risk of death or injury by collapse of excavation side wall 3. Damage to plant 4. Excessive run-off into surface watercourses 5. Loss and cessation of works	3	5	15	1. Review of previous excavations in the locality and in similar ground 2. Walkover, survey and map route to identify soft ground areas, bogholes, swallowholes, springs, streams (surface and subterrain) 3. Detailed site investigation to include trial trenches to expose soils 4. Measurement of groundwater from piezometers where possible 5. Detailed method statement to be prepared with respect to dewatering and protection of works. 6. Installation of low permeability plugs in stone road	1. No/Restricted access into excavation 2. Appropriate pumping/dewatering facilities to be put in place during the construction phase. 3. Employment of contractor/personnel familiar with soft ground conditions 4. Supervision to ensure construction carried out as detailed in the method statement	1	5	5	1. Stop work 2. Assess situation 3. Deploy engineering solution to dewater 4. Install low permeability plugs in or in close proximity to areas where there is water ingress 5. Monitor situation 6. Reserve / additional pumping facilities to be available
13	**Failure of base of excavation (piping/heave)**	1. Unexpected weak ground conditions below excavation 2. Temporary localised head pressure present due to the elevation differences between trench and surrounding ground 3. Over-excavation in weak ground	1. Health & Safety 2. Programme 3. Cost	1. Risk of injury 2. Damage to plant 3. Excessive deformation of base of excavation 4. Settlement of surrounding ground and possible failure of excavation sides 5. Loss and cessation of works	2	5	10	1. Review of previous excavations in the locality and in similar ground 2. Detailed site investigation to include trial trenches to expose soils 3. Boreholes and trial pits to be taken below base of excavations 4. Measurement of groundwater from piezometers where possible 5. Detailed method statement to be prepared in accordance with ground conditions anticipated	1. Site supervision staff to inspect trench 2. No/Restricted access into excavation 3. Areas of heave and/or piping to be reported 4. Employment of contractor/personnel familiar with soft ground conditions 5. Engineering supervision to ensure construction carried out as detailed in the method statement 6. Limited exposure of excavation base and sides to avoid potential for failure	1	4	4	1. Stop work 2. Ballast stone to be placed at base of excavation 3. Reserve pumping facilities to be available 4. Use of settlement tanks 5. Divert water from settlement tanks into drainage channels/onto bog surface where appropriate 6. Use straw bales/terram in drainage channels

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14	**Presence of clay /silt with low shear strength below peat**	1. Unexpected loss of strength 2. Loading/vibration/excavation	1. Health & Safety 2. Programme 3. Cost	1. Risk of death or injury 2. Damage to plant 3. Loss and cessation of works 4. Collapse of excavation sides 5. Peat slide	2	5	10	1. Review of previous excavations in the locality and in similar ground 2. Detailed site investigation to include trial trenches to expose sensitive soils 3. Boreholes and trial pits to be taken below base of excavations 4. Avoidance of excessive loading and/or excessive vibration 5. Detailed method statement to be prepared in accordance with ground conditions anticipated	1. Site supervision staff to inspect trench 2. No/Restricted access into excavation 3. Employment of contractor/personnel familiar with soft ground conditions 4. Engineering supervision to ensure construction carried out as detailed in the method statement 5. Limited exposure of excavation base and sides to avoid potential for failure 6. Avoid excessive loading and/or vibration	1	5	5	1. Stop work 2. Ballast stone to be placed at base of excavation 3. Stone to be placed downslope of any potential peat movement 4. Remove excess loads 5. Avoid excessive vibrations
15	**Peat slide**	1. Unexpected weak ground conditions. 2. Intense rainfall event 3. Improper construction	1. Health & Safety 2. Environmental 3. Programme 4. Cost	1. Risk of death or injury by inundation 2. Environmental damage 3. Damage to persons, plant, property and livestock 4. Loss and cessation of works 5. Adjacent land affected due to peat/ground movement	2	5	10	1. Carry out detailed site investigation 2. Walkover survey of route to identify areas of potential failure 3. Obtain good understanding of stability of site and possible mechanism that might trigger ground movement 4. Assessment of potential for peat failure 5. Design conservatively to eliminate all mechanisms likely to trigger movement 6. Detailed method statement to be prepared	1. Site supervision staff fully briefed on ground conditions 2. Provision and monitoring of geotechnical instrumentation to record ground movement and groundwater pressures where appropriate 3. Control of all construction practices so that all works on site are within design conditions 4. Continual site inspection of site for evidence of ground movements 5. Sheet piles readily available 6. Impede surface water's access to failed area 7.Provide suitably qualified person to supervise/monitor remedial works 8. Supervision to ensure construction carried out as detailed in the method statement	1	5	5	1. Stop works 2. Use sheetpiling to stop ground movements 3. Monitor movements following installation of sheetpiles until movements have ceased 4. Reduce speed of works 5. Reduce excavation lengths prior to backfilling with stone
16	**Settlement of stone road in peat prior to pipeline installation**	1. Inadequate site investigation information 2. Inadequate stone road construction	1. Programme 2. Cost	1. Delays to works	2	3	6	1. Detailed site investigation to include trial trenches to expose and record soils 2. Boreholes and trial pits to be taken below base of pipeline trench 3. Detailed stone road method statement to be prepared 4. Specify appropriate instrumentation along stone road	1. Site supervision staff fully briefed on ground conditions 2. Employment of contractor/personnel familiar with soft ground conditions 3. Provision and monitoring of geotechnical instrumentation to record ground movement and groundwater pressures where appropriate 4. Control of all construction practices so that all works in accordance with method statements 5. Continual site inspection of road for evidence of settlement/movement 6. construction traffic will provide necessary compaction to stone road	1	3	3	1. Increase frequency of monitoring/install futher instruments 2. Provide additional surcharge loading of road 3. Excavate affected length of road and re-compact road fill 4. Additional trafficking on stone road to prodive additional compaction

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Tunnelling													
1	**Subsidence/loss of ground at ground surface due to tunnelling** **Sinking/excessive settling of ground.**	1. Variable ground conditions on tunnel line with zones of weaker ground 2. Weathered rock, areas of fractured rock such as at fault/shear zones 3. Flushing out of weak material in cavities or fractures from tunnelling	1. Programme 2. Cost 3. Environment	1. Subsidence at ground level	1	2	2	1. Carry out detailed site investigation along the route to verify ground conditions particularly variable ground, zones of weaker ground 2. Carry out geophysical surveying (completed 2007) and tie-in of survey with borehole information 3. In particular determine rockhead profile where tunnelling is to below/above rockhead 4. Review of detailed site investigation and re-evaluate areas of unusual ground or where highly variable 5. Produce ground model along tunnel corridor 6. Revise vertical tunnel trajectory to suit ground conditions 7. Use of conservative design parameters for ground 8. Selection of tunnelling methodology (segment lined tunnel) 9. Tunnel segments to be grouted in place (there will be no void space around the tunnel segments which could subsequently lead to subsidence. Tunnel will be firmly embedded within surrounding ground.	1. Supervising staff and construction staff to be fully briefed on particular ground conditions 2. Employment of contractor/personnel familiar with tunnelling in such ground conditions 3. Tunnel designers risk assessment and method statement for construction 4. Comprehensive and regular monitoring of tunnel works to provide advance notice of potential problems 5. Tunnel segments are grouted externally with cement.	1	1	1	1. Stop works 2. Assess ground movements 3. Adjust parameters of drilling fluid operating system (flow rate, composition, pressure) 4. Adjust rate of progress
2	**Unexpected ground conditions e.g. hard strata, alternating hard / soft strata, boulders, rock outcrops or man made objects (manageable by boring process)**	1. Ground conditions differing from those indicated from site investigation 2. Presence of boulders/ bedrock 3. Presence of difficult to drill natural/man-made object 4. Unexpected change in geology / ground conditions 5. Combination of alternating hard/soft ground conditions 6. Variable weathered rock conditions	1. Programme 2. Cost	1. Delay due to reduced tunnelling rate 2. Cost due to reduced tunnelling rate	2	2	4	1. Selection of tunnelling method: Segment Lining technology tunnelling is suitable for soft and hard rock 2. Carry out geophysical surveying (completed 2007) and tie-in of survey with borehole information 3. Carry out detailed site investigation along the route to verify ground conditions particularly variable ground, zones of weaker ground 4. Tie-in the geophysical survey to borehole information from site investigation 5. In particular determine rockhead profile where tunnelling is below/above rockhead 6. Review of detailed site investigation and re-evaluate areas of unusual ground or where highly variable 7. Revise tunnel route to suit ground conditions 8. Select a vertical alignment based on site investigation/geophysical information and laboratory testing results 9. Produce ground model along tunnel trajectory 10. Use of conservative design parameters for ground for tunnelling design (tunnel boring machine head design) 11. Conservative tunnel performance specification to allow for durable and robust tunnel boring machine and reserve critical plant	1. Supervising staff and construction staff to be fully briefed on particular ground conditions 2. Employment of contractor/personnel familiar with tunnelling in mixed ground conditions - exceute a robust tendering process 3. Tunnel designer to carry out risk assessment and detailed method statement for construction 4. Comprehensive and regular monitoring of tunnel works to provide advance notice of potential problems 5. Check cutting returns, type, shape, mass balances 6. Check data collected by instrumentation in TBM (pressure, flow, temp, video, torque of cutting wheel, speed etc) 7. Check position/positioning system continuously (is the TBM on predetermined trajectory/alignment?) 8. Check investigation data/ground model 9. Check thrust force versus geology and profile 10. Check if rotational direction of cutting wheel can be changed. 12. Man entry for inspection or repair of TBM 12. Man entry in front of the TBM (to cutting head) 13. Man entry (to cutting head) to break an obstacle	1	2	2	1. Attempt to be undertaken to fix/secure/break the object from within the TBM or from outside (e.g to drill through the obstacle). 2. Change tools in cutting head via airlock in TBM and Prepare for regular tool change out at cutter head. 3. Develop entry procedures for removal of obstruction from inside installed cutting head (will require working within airlock) 4. Confirm that appropriate level of relevant specialised tunnelling experience for this situation is present.
3	**Loss of bentonite slurry from tunnel face due to unexpected variable ground conditions** **Bentonite escaping through fissures/openings at bore depth**	1. Ground conditions differing from those indicated from site investigation 2. Zones of higher permeability soils	1. Environmental 2. Programme 3. Cost	1. Delay due to reduced tunnelling rate 2. Excessive leakage of bentonite into ground with possible environmental impact 3. Cost of remediation due to bentonite breakout	2	5	10	1. Use of segment lining requires bentonite circulation at the head of TBM. No bentonite is required to be injected along tunnel. 2. Carry out geophysical surveying (completed 2007) and tie-in of survey with borehole information 3. Carry out detailed site investigation along the route to verify ground conditions particularly variable ground, zones of weaker ground 4. In particular determine rockhead profile where tunnelling is below/above rockhead 5. Review of detailed site investigation and re-evaluate areas of unusual ground or where highly variable 6. Produce ground model along tunnel corridor 7. Revise vertical tunnel trajectory to suit ground conditions 8. Use of conservative design parameters for ground 9. Carry out the bentonite operating evelope calculation. Method statement to include the bentonite operaton envelope.	1. Monitor bentonite mass balance 2. Monitor bentonite system operating pressures 3. Adjust drilling fluid characteristics: composition / density / viscosity / use of polymers 4. Surface inspection/monitoring	1	3	3	1. Stop work 2. Adjust bentonite mix 3. Injection of grout to stabilise surrounding ground
4	**Tunnel pit / shaft failure/water logging.**	1. Design error (wrong interpretation of geotechnical data) 2. Construction error 3. Unexpected zone of weak ground	1. Health & Safety 2. Programme 3. Cost	1. Loss and cessation of works 2. Delay due to reduced tunnelling rate 3. Cost due to reduced tunnelling rate 4. Cost of repairs	3	2	6	1. Carry out detailed site investigation at site of shaft/adit location along the route to verify ground conditions particularly variable ground, zones of weaker ground 2. In particular determine rockhead profile and rock condition where anchors/support piles to be located in rock 3. Review of detailed site investigation (determined based on preferred tunnel route) 4. Produce ground model at shaft/adit sites 5. Use of conservative design parameters for ground 6. Independent design verification 7. Capable contractor with proven track record in complex foundation construction	1. Check ground investigation data 2. Supervising staff and construction staff to be fully briefed on particular ground conditions 3. Employment of contractor/personnel familiar with tunnelling in such ground conditions 4. Detailed method statement and specific tunnel risk assessment 5. Comprehensive and regular monitoring of shaft/adit to provide advance notice of potential problems 6. Pumping of water from shaft/adit	1	4	4	1. Stop work 2. Remedial work to repair shaft/adit

Corrib Onshore Pipeline

Geotechnical Risk Register

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May, 2010

No.	Hazard	Cause	Potential Impact		Risk Rating (Refer Table 12.1 and 12.2)			Risk Control Measure (RCM)		Risk Rating following RCM (Refer Table 12.1 and 12.2)			Contingency Measures
			Category	Specific	P	I	R	Design Control	Construction / Operations Control	P	I	R	
Temporary Works													
1	**Failure of bog mat access road**	1. Overloading of the underlying soft peat soils. 2. Insufficient understanding of the variability of the strength within the peat. 3.Localised softer/weaker pockets within the peat. 4. incorrect use of bog mats and bog mat road	1. Health & Safety 2. Programme 3. Cost	1. Risk of death or injury by fall/crushing plant. 2. Damage to plant 3. Loss and cessation of works	3	5	15	1. Carry out detailed site investigation along the route of the access road to determine variability of the peat/soft ground strengths 2. Walkover survey of route to identify areas of potential softer ground 3. Determine areas suitable for bog mats 4. Require contractor to provide detailed construction method statement 5. Undertake supervision and monitoring regime on site works	1. Supervising staff and construction staff to be fully briefed on the ground conditions, temporary works design requirements (in particular loading limitations) and construction methodology 2. Supervision to ensure that the construction is carried out as detailed in the method statement 3. Comprehensive and regular monitoring and comparison of predicted ground behaviour with observed ground behaviour 4. Inspection after significant rainfall event 5. Preparation of areas if significant rainfall forecasted	1	5	5	1. Stop works 2. Use additional bog mats. 3. Install stone road
2	**Failure of pipeline trench slopes during installation of pipe**	1. Unexpected weak ground 2. Localised slope failure 3. Water ingress 4. Plant too close to excavation 5. Slopes too steep	1. Health & Safety 2. Programme 3. Cost	1. Risk of death or injury by collapse of trench side wall 2. Damage to plant 3. Loss and cessation of works	4	5	20	1. Detailed site investigation to include trial trenches to expose soils 2. Boreholes and trial pits to be taken below base of pipeline trench 3. Use of conservative soil parameters for temporary design 4. Conservative design of propping system, where used 5. Detailed method statement for the works	1. No/Restricted access into excavation 2. Employment of contractor/personnel familiar with soft ground conditions 3. Geotechnical supervision to ensure slope batter appropriate to soil conditions 4. Supervision to ensure construction is carried out as detailed in the method statement	1	4	4	1. Stop work 2. Remove failed material 3. Batter back to safe angle OR install temporary support 4. Review pipe installation procedure
3	**Failure of pipeline trench excavation in stone road**	1. Localised slope failure 2. Water ingress 3. Plant too close to excavation 4. Slopes too steep	1. Health & Safety 2. Programme 3. Cost	1. Risk of death or injury by collapse of trench side wall 2. Damage to plant 3. Loss and cessation of works	2	5	10	1. Excavation slopes to be specified 2. Detailed method statement to be prepared to include Health and Safety requirements for open excavations 3. Use of conservative design parameters	1. Appropriate sequencing of works 2. Geotechnical supervision of works 3. Tool box talks to be carried out prior to works 4. Use shoring or trench boxes if sloped sides are not possible 5. Supervision to ensure construction carried out as detailed in the method statement	1	5	5	1. Stop work 2. Review cause of failure 3. Ensure safe distance of plant 4. Review pipe installation procedure
4	**Failure of pipeline trench support (where used)**	1. Unexpected ground conditions - weaker and deeper 2. Embedment of sheet piles not sufficient 3. Failure of trench box/shoring	1. Health & Safety 2. Programme 3. Cost	1. Risk of death or injury by collapse of trench side wall 2. Damage to plant 3. Loss and cessation of works 4. Collapse of excavation sides	4	5	20	1. Detailed site investigation to include trial trenches to expose soils 2. Boreholes and trial pits to be taken below base of pipeline trench 3. Use of conservative soil parameters for temporary design 4. Conservative design of propping system, where used 5. Check of implications of over-excavation 6. Specify method statement from the Contractor on trench support	1. Site supervision staff to inspect temporary retaining structure on daily basis 2. No/Limited access into trench 3. Monitoring of sheet pile movements during construction where appropriate 4. Provision of additional temporary propping systems to be available on site during excavation phase 5. Supervision to ensure installation of support carried out as detailed in the method statement 6. Buddy system for people working in trench, never alone onsite or in the trench	1	4	4	1. Stop work 2. Install additional lateral supports 3. Use longer / larger sheet piles 4. Use stone road approach
5	**Damage/disturbance of monitoring instruments**	1. Construction damage 2. Third party damage 3. Improper installation	1. Programme 2. Cost	1. Delays to works	4	2	8	1. Provide sufficiently robust instruments and protection 2. Provide sufficient redundancy 3. Locate instruments in safe locations	1. Construction personnel briefed on importance/location of instruments 2. Provide clear signage and protection 3. Re-locate instruments	1	2	2	1. Avoid work in area where possible 2. Re-establish instruments
6	**Failure of granular stone/geogrid reinforced access road**	1. Overloading of the underlying soft peat soils. 2. Insufficient understanding of the variability of the strength within the peat. 3.Local softer/weaker pockets of underlying material 4. incorrect installation of geogrids	1. Health & Safety 2. Programme 3. Cost	1. Risk of death or injury by fall/crushing plant. 2. Damage to plant 3. Loss and cessation of works	3	5	15	1. Carry out detailed site investigation along the route of the proposed road to determine variability of the peat/soft ground strengths 2. Walkover survey of route to identify areas of potential softer ground 3. Design temporary access roads based on good working practice within the industry – e.g. proven practices within Bord na Móna 4. Determine areas suitable for temporary access roads 5. Require contractor to provide detailed construction method statement 6.Undertake supervision and monitoring regime on all site works.	1. Supervising staff and construction staff to be fully briefed on the ground conditions, design requirements (in particular loading limitations) and construction methodology 2. Supervision to ensure that the construction is carried out as detailed in the method statement 3. Comprehensive and regular monitoring and comparison of observations with predicted ground behaviour. 4. Inspection after significant rainfall event 5. Preparation of areas if significant rainfall forecasted	1	5	5	1. Stop works 2. Install stone road/bog mats 3. Install stone road
7	**Installation of temporary sheet piles**	1. Unexpected ground conditions. 2. Slope angle steeper than expected 3. Excessive groundwater inflow 4. Declutching of sheets	1. Health & Safety 2. Environmental 3. Programme 4. Cost	1. Risk of injury during installation 2. Damage to plant 3. Change of hydrology 4. Loss and cessation of works	2	4	8	1. Carry out detailed site investigation along the route of the proposed road 2. Walkover survey of route 3. Appropriate pile type to be selected 4. Detailed method statement to be prepared for sheet pile installation 5. Hydrology of area to be considered during sheet pile design	1. Installation of sheet piles to be supervised by appropriately experienced personnel 2. Use appropriate equipment and sheets 3. Installation to be carried out by competent contractor 4. Installation to be stand-alone task and should not interfere with other works 5. Supervision to ensure construction carried out as detailed in the method statement	1	4	4	1. Stop works 2. Record and report problem 3. Install stone road where appropriate

Corrib Onshore Pipeline

Geotechnical Risk Register

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			Category	Specific	P	I	R	Design Control	Construction / Operations Control	P	I	R	
8	**Failure of temporary sheet piles**	1. Unexpected soft ground conditions. 2. Excessive groundwater inflow 3. Mechanical failure of pile 4. Insufficient embedment depth	1. Health & Safety 2. Environmental 3. Programme 4. Cost	1. Risk of injury or death by failure of piles or associated ground movement 2. Damage to plant 3. Adjacent land affected due to peat/ground movement 4. Trigger major slide with damage to property, persons, livestock	3	5	15	1. Carry out detailed site investigation along the route 2. Walkover survey of route 3. Undertake test pile to determine suitability of installation 4. Monitoring of installation 5. Detailed method statement to be prepared	1. Competent person to install piles with suitable equipment 2. Piles damaged during installation to be replaced. 3. Provide adequate working platform (refer to bog mat risks) 4. Regular inspection and monitoring of piles and supported ground/peat. 5. Drainage ditches and water courses to be monitored and maintained. 6. Supervision to ensure construction carried out as detailed in the method statement	1	5	5	1. Stop works 2. Record and report problem 3. Install stone road
9	**Recovery of plant and equipment**	1. Plant stuck in bogholes 2. Plant sliding off haul roads or bog mats 3. Plant caught in displaced peat 4. Localised slip failure of stone road	1. Health & Safety 2. Environmental 3. Programme 4. Cost	1. Risk of injury or death to personnel 2. Damage or loss of plant 3. Spillage of fuel and oil	3	5	15	1. Working area extents to be pegged 2. Use of appropriate plant 3. Design to consider abnormal loading 4. Detailed method statement to be prepared for the works 5. Temporary recovery access to be designed specifically for recovery works	1. Spill kits around plant and involvement of environmental expert to ensure containment of spillages 2. Removal of potential and actual contaminants as required. 3. Develop clear plan of action prior to recovery operation 4. Works supervised by experienced personnel 5. Use of correct lifting equipment, slings and recovery/winch cables 6. Damaged plant to be removed to safe area 7. Supervision to ensure recovery carried out as detailed in the method statement	1	5	5	1. Stop works 2. Use alternative plant for works 3. Increase width of access roads where feasible and appropriate

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In Operation													
1	**Settlement/soft ground in pipe trench backfill**	1. Poorly compacted backfill 2. Inadequate backfilling 3. Inadequate soil strength at base of trench	1. Health & Safety 2. Cost	1. Risk of injury by tripping/ bogging of plant 2. Damage to farm plant and land 3. Surface depressions manifested	3	4	12	1. Consider alternatives for the backfilling of the trench (introduction of brushwood, geogrid) that will not alter the hydrogeology of that area of the site long term 2. Highlight on drawings the need to cordon off the trench post construction and also the need to provide discrete crossing points for plant and personnel to facilitate safe movement around the site 3. Detailed method statement to be prepared 4. Mounding of backfill where appropriate to accomodate subsequent consolidation 5. Determine likely time for backfill to consolidate and ground to become stable 6. Specify re-inspection of re-instated areas and follow-up work as necessary	1. Supervision staff to be fully briefed on the ground conditions, design requirements and construction methodology 2. Cordon off of areas of weak/soft ground 3. Supervision to ensure reinstatement/backfilling carried out as detailed in the method statement 4. Re-inspection of reinstated areas post consolidation period	1	4	4	1. Dig out material around pipe and replace and recompact 2. Import approved material to re-grade if necessary
2	**Erosion of overburden cover to buried pipe in river/stream crossings (eg 2003 rainfall event)**	1. Intense rainfall and associated run-off conditions	1. Health & Safety 2 Environmental 3. Cost	1. Damage to pipeline coating (concrete) 2. Cost due to shut-down and repair (if required)	2	3	6	1. Specify as-built records to provide details of actual level/line of pipe in ground 2. Walk-over survey to identify river/stream crossings and depth of alluvial sediments 3. Adequate protection measures (e.g. concrete coaeted pipe) / burial depths identified based on conservative values 4. Burial depth to consider significant stream bed erosion due to extreme rainfall events 5. Detailed method statement to be prepared 6. Installation of concrete slabs above pipeline where the bottom of the drain/ditch may be lowered (as per I.S. 328)	1. Supervision staff to be fully briefed on the ground conditions, design requirements and construction methodology 2. Supervision to ensure construction carried out as detailed in the method statement 3. Control of line and level of pipe in ground	1	1	1	1. Divert river/stream (temporary measure) 2. Backfill and strengthen backfill material 3. Increase depth of pipeline / add additional cover for protection
3	**Erosion of seaward cliff at landfall**	1. Unexpected storm conditions	1. Health & Safety 2 Environmental 3. Cost	1. Coastal erosion and loss of natural environment	3	2	6	1. Walk-over of cliff line to identify extent of erosion and soils/rock within cliff 2. Use of conservative design parameters for design of sea cliff 3. Use of conservative erosion/wave action 4. Re-instated sea cliff to be robust and also to be sympathetic to existing natural cliffs 5. Detailed construction method statement to be prepared	1. Site supervision staff fully briefed on ground conditions and tidal working 2. Re-use of acceptable as-dug materials to re-construct cliff 3. Supervision to ensure that cliff is re-constructed as per method statement and is sympathetic to existing sea cliffs 4. Regular inspections of the cliff face (especially after storms)	1	4	4	1. Monitor cliff face and replace material if necessary.
4	**Peat slide**	1. Unexpected weak ground conditions. 2. Intense rainfall event 3. Peat movement from outside site	1. Health & Safety 2. Environmental 3. Programme 4. Cost	1. Risk of death or injury by inundation 2. Environmental damage 3. Damage to plant 4. Cost due to shut-down and repair	2	5	10	1. Carry out detailed site investigation 2. Walk-over survey of route to identify areas of potential failure 3. Obtain good understanding of stability of site and possible mechanism that might trigger ground movement 4. Assessment of potential for peat failure 5. Design conservatively to eliminate all mechanisms likely to trigger movement 6. Carry out sensitivity test to show performance of pipe with different failure scenarios 7. Specify robust pipe construction (stone road method) 8. Assess stability of stone road under flooded conditions	1. Maintenance requirement to include regular walkover inspection of pipeline route 2. Walkover inspection to be carried out by suitably qualified persons 3. Report of walkover inspection to determine existing stability of peat and any works required and to recommend time period for next walkover 4. Monitoring of peat next to stone road using inclinometer probes and piezometers 5. Long term monitoring using ground survey markers	1	5	5	1. Install sheet piling to stop ground movements 2. Monitor movements following installation of sheetpiles 3. Maintain drains and ditches locally
5	**Creep movement/ settlement of pipe due to movement of soil**	1. Insufficient understanding deformation properties of surrounding soil 2. Inadequate site investigation information 3. Inadequate design.	1. Health & Safety 2 Environmental 3. Cost	1. Damage to facility	1	2	2	1. Detailed site investigation to include trial trenches to expose and record soils 2. Boreholes and trial pits to be taken below base of pipeline trench 3. Pipeline designers to include for potential creep movement 4. Pipeline to be laid onto competent bedding 5. Tolerances for movement to be specified 6. Detailed method statement to be prepared	1. Site supervision staff fully briefed on ground conditions 2. Employment of contractor/personnel familiar with soft ground conditions 3. Supervision to ensure that pipeline installed as per method statement 4. Develop procedures for regular pipeline route inspection 5. Long term monitoring using GPS plates if possible	1	1	1	1. Install measures to prevent excess movements e.g. sheetpiles/extend stone road