April 3, 2007-04-13 NRCan File # NS-049

Hearing Order GH-2-2006
File No. OF-Fac-Gas-E112-2006-02

Eric Theriault
Advisor Environmental Affairs
Canada – Nova Scotia Offshore Petroleum Board
1791 Barrington Street
Halifax, Nova Scotia B3J 3K9

Subject: Natural Resources Canada – Review of the Draft Comprehensive Study Report and the Environmental Assessment Report for the Deep Panuke Offshore Gas Development Project

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Dear Mr. Theriault:

Natural Resources Canada (NRCan) has determined as per the *Regulations Respecting the Coordination by Federal Authorities of Environmental Assessment Procedures and Requirements* of the *Canadian Environmental Assessment Act* (CEAA) that it was a federal authority in possession of specialist or expert information or knowledge with respect to this project. NRCan is an economic science-based department with a mandate to promote sustainable development and responsible use of Canada's energy, minerals, and forestry resources, and to develop an understanding of Canada's landmass. The Department conducts research and technical surveys to assess Canada's resources, including the geological structure, as well as scientific and economic research related to the energy, forestry, mining and metallurgical industries.

NRCan has completed its review of the draft Comprehensive Study Report and the proponent's Environmental Assessment Report, and is providing its comments for consideration pursuant to the Department's role as a federal authority under CEAA. Based on the information provided in the above mentioned documents, NRCan is providing comments in the following topic areas that are within its mandated expertise:

- Seismicity;
- Nearbed hydrodynamics;
- Seabed stability;
- Sediment transport; and
- Marine geology.

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Details of the comments are provided in the attachment. It is also hoped that NRCan may have an opportunity to provide comments with respect to the geotechnical testing program that is to be included as part of the project's environmental protection plan, once the details of this program are available.

Should you require additional information or clarification on the comments provided by NRCan, I invite you to contact me by email at curtis.lockett@nrcan.gc.ca or by phone at (613) 482-1444.

Sincerely,

Curtis Lockett
Environmental Assessment Officer

Enclosure

Natural Resources Canada Comments
Deep Panuke Offshore Gas Development Project in Nova Scotia Environmental Assessment Report (November 2006) and Comprehensive Study Report (April 2007)

Natural Resources Canada (NRCan) is pleased to provide comments on the above-mentioned documents within the mandate of NRCan's Earth Sciences Sector. Three ESS scientists from the Geological Survey of Canada (GSC) (one from GSC-Central and two from GSC-Atlantic) have provided expertise on seismicity, nearbed hydrodynamics, seabed stability, sediment transport processes and marine geology.

The detailed comments are provided in the following pages.

Reviewer A

Areas of Expertise

Seismicity

Documents Reviewed

1. Deep Panuke Offshore Gas Development Environmental Assessment Report. Prepared by: EnCana Corporation, November 2006
2. Comprehensive Study Report: Deep Panuke Offshore Gas Development Project, EnCana Corporation. Prepared by: the Canada-Nova Scotia Offshore Petroleum Board, the National Energy Board, Fisheries and Oceans Canada, Environment Canada, Transport Canada, and Industry Canada, April 2007
3. Responses to Natural Resources Canada Information Requests (http://www.neb-one.gc.ca/fetch.asp?language=E&ID=A0X5U4). Prepared by: EnCana Corporation, January 2007

Comments on draft Comprehensive Study Report (April 2007)

There appears to be no specific mention of seismic activity or earthquake (as judged by key-word search). However, the key section for seismic concerns is likely related to Section 9.13: "Effects of the Environment on the Project", in which the "Certificate of Fitness" is to be required from the proponent by the certifying authority. This is area of concern has also been elaborated on by the proponent in their information request response, which NRCan considers satisfactory (see below).

Comments on the Information Request Response (January 2007):

Request:	**Response**:	**NRCan reply**
(a) Please confirm whether the seismic hazard assessment will be performed in accordance with the CSA S471.	CSA S471, as specified in the CNSOPB Installation Regulations, is the design code to which offshore structures in Canada shall be designed including seismic hazard assessments. However, as stated in CSA S471, Section 1.2, Alternative Design Procedures, alternative codes can be used if an equivalent level of safety and serviceability is achieved. Any seismic assessment for the Deep Panuke development shall be completed by the appropriate engineering contractor. If a contractor proposes an alternate code for seismic assessment, this shall be approved by EnCana, the project Certifying Authority and the CNSOPB via a Regulatory Query Form (RQF). If the RQF is approved by all three parties, an alternative method may be used. Therefore, we confirm that the seismic hazard assessment for the Deep Panuke development shall be performed in accordance with CSA S471 or equivalent.	Accepted
(b) Please provide additional information at to who will be reviewing the specific seismic analysis (to) be performed during detailed design".	Seismic analyses shall be reviewed by the EnCana engineering team and reviewed and approved by the project Certifying Authority.	Accepted
(c) Please indicate whether the earthquake probability level of 0.0004 per year has been approved by regulatory authorities.	The value of 0.0004 per year was approved by the Certifying Authority in 2002.	Accepted
(d) Please provide a copy of the "EnCana Offshore Seismic Safety Manual" cited in section 4.3.of the EAR.	The "EnCana Offshore Seismic Safety Manual" referenced in the approved 2002 CSR was a manual for seismic data acquisition for drilling targets with no relation to seismic hazards. This manual is no longer used by EnCana.	Accepted and understood

Reviewer B

Area of Expertise

Marine geology

Documents Reviewed

1. Responses to Natural Resources Canada Information Requests (http://www.neb-one.gc.ca/fetch.asp?language=E&ID=A0X5U4). Prepared by: EnCana Corporation, January 2007

Comments on the Information Request Response (January 2007):

Request:	**Response**:	**NRCan reply**
(a)What is the role of the "protection" structure? Is this permanent? Is suspended sediment, scour and/or potential for deposition/burial a factor considered in its design?	1. The role of the "hot tap" protection structures is the same as for the "wellhead protection structures" described in Section 4.6.2 of the Development Plan (Volume 2). The protection structures will protect the equipment housed within it from dropped objects, dragging anchors, and fishing gear.	Accepted
(b) Is this structure permanent?	The protection structures are permanent during the operations phase of the Deep Panuke Project. During the decommissioning phase, all subsea facilities above the seafloor, including protection structures, will be decommissioned in accordance with applicable regulation at the time as discussed in Section 4.10 of the Development Plan (Volume 2).	Accepted
(c) Is suspended sediment, scour and/or potential for deposition/ burial a factor considered in its design?	Yes, suspended sediment, scour and/or potential for deposition/burial are factors that will be considered during the design.	Accepted
(a) Please provide further clarification and supporting information as to rationale for considering pipeline, flowline and umbilical trenching and burial.	The decision to bury a pipeline is predominantly based upon on-bottom stability, protection, and insulation requirements. The rationale/reason for the export pipeline and flowlines trenching and burial is specifically stated for each component in the Activity/Purpose column of Table 2.2 of the Environmental Assessment (EA) Report (Volume 4). The rationale/reason for the trenching and burial of the umbilical is for on-bottom stability and protection.	Accepted

(b) Please provide reference and information regarding the direct knowledge that the Applicant's design engineers have on appropriate or site-specific (i.e. Sable Island Bank in approximately 40 m water depth) sediment transport conditions. Additionally, please indicate whether this information has been gained through analogy with other sites (e.g. North Sea), or from site-specific geotechnical measurements of the sands.	The best information and direct knowledge for the Sable Island Bank in approximately 40 m water depth is from the EnCana-operated Cohasset Project. The Cohasset Project was installed in 1991 and final decommissioning occurred in 2005. The project comprised two fixed platforms, a mobile offshore production and drilling unit, 25 km of flowlines, 10 km of umbilical (i.e., power and communication cable), two pipeline end manifolds (PLEMs), a catenary anchored leg mooring buoy and a floating storage offloading tanker. The Cohasset Project facilities ranged in water depth of 35 m to 45 m and encompassed an area of approximately 10 km long x 3 km wide. The subsea facilities have undergone extensive subsea inspections, the latest being the final decommissioning project closeout/monitoring survey performed in fall 2006. The Deep Panuke mobile offshore production unit, wells, subsea protection structures, flowlines and umbilical will essentially be located in the same area as the Cohasset Project. This knowledge from the Cohasset Project, specifically the monitoring of the subsea flowlines, umbilical, PLEMs and platform piles, will be used for the design of the Deep Panuke project. Based on its Cohasset experience, EnCana agrees with GSC research that 1 m burial is sufficient in water depths of approximately 40 m.	Accepted
(c) Please indicate whether and how the design plan will address the probability of buried pipeline disturbance during the project's lifespan, and what mitigation measures will be implemented in this event. As this is a potential pipeline integrity issue, please include information regarding when, and by what technique(s), will sediment transport and sediment disturbance depth be assessed for the project. Similarly, please indicate when and by what mechanism will "outside" (e.g., regulatory) expertise be able to input, evaluate and provide feedback on the environmental constraints that are to be factored into facility design.	The design plan will be to bury flowlines, umbilicals and the pipeline (if necessary) deep enough to ensure that they will not be disturbed by the subsea environment. Once the components have been installed, an as-built (i.e. baseline survey) will be performed to confirm the location, depth of cover, water depth and provide a record of the installed seabed conditions. During the operational phase of the Deep Panuke Project, a subsea inspection program will monitor the condition of the subsea components and compare to the baseline data and original design parameters for any changes. The primary subsea inspection technique used is a remotely operated vehicle (ROV) survey with a pipetracker device. As well, geophysical survey techniques can be used such as sidescan sonar, subbottom profiler and magnetometer. If any pipeline integrity issues are found as a result of the survey, the cause will be assessed and corrective actions will be taken as required for each particular incident. As described in section 4.2.2 of the Development Plan (Volume 2), the Project facilities will comply with applicable CNSOPB regulatory requirements. The CNSOPB requires an independent third party known as a certifying authority (CA) to confirm, through design appraisal and work survey, that all Project facilities and structures have been designed, constructed, transported and installed in accordance with the Nova Scotia Offshore certificate of Fitness Regulations. This includes the environmental constraints that are to be factored into facility design. This confirmation is proved in the form of a Certificate of Fitness (COF) issued by the CA; the CA will have access to all relevant Deep Panuke data in making its COF evaluation. This COF is required to be maintained for the duration of the Deep Panuke project life, until the facilities have been decommissioned.	Accepted

(d) Please provide the mitigation measures/ procedures that are to be in place in the event of significant pipeline exposure to harsh environmental conditions where not buried, as well as the potential seabed footprint of such mitigating solutions.	For sections where the pipeline is not buried, the mitigation measure is to design the pipeline with sufficient on-bottom stability to withstand the 100 year storm event and enough inherent strength to withstand impacts from fishing activities without compromising pipeline integrity. No additional seabed footprint is required by this solution.	Accepted
(a) Please provide information concerning when, and under what knowledge constraints, would the decision be taken to allow natural versus mechanical backfill.	As discussed in Table 2.2 of the Environmental Assessment Report (Volume 4), the three primary reasons to bury the pipeline, flowlines and umbilicals are for on-bottom stability, protection and insulation. Natural backfill would be considered when the reason for burial is for on-bottom stability; provided that the on-bottom stability design demonstrates that the pipeline is stable when located in an uncovered trench and protection and insulation are not a requirement.	Accepted
(b) Please indicate whether there will be provision for slow (i.e., several years) natural burial; if so, please provide information concerning whether the facility will be at an increased risk during the period where components are unburied.	As described above, the primary reason to allow natural backfill is for on-bottom stability when the pipeline is stable in the uncovered trench and protection and insulation are not of a concern. In this situation, the pipeline will not be at an increased risk during the unburied period because the design of the pipeline will take into consideration the unburied condition of the pipeline.	Accepted
(c) If the decision for mechanical backfill is taken, please indicate where the sediment will be collected from, and how will it be moved to the appropriate locations. Please indicate the likely seabed footprint of such an operation.	Backfill sediment is “collected” from underneath the pipeline/ flowline/ umbilical and will be placed on top of the pipeline/ flowline/umbilical. The likely seabed footprint is based upon the diameter of the pipeline/flowline/umbilical being trenched, the depth to which they are being trenched, soil conditions encountered (i.e., due to the required V-shape of the trench for it to be stable) and trenching equipment size. A rough footprint estimate considering the above variables is likely to be in the order of a few diameters of the pipeline/flowline/umbilical being trenched.	Accepted
(a) Please indicate the approximate seabed footprint of the wellhead and how is it supported.	The actual wellhead component will be supported on the 762 mm [30-inch] drilling conductor which is ‘set’ approximately 100 m below the seabed. The surface and production casing strings will be tied back to the subsea wellhead via the existing mudline suspension system. The production tubing will be landed in the subsea production tree via a conventional tubing hanger. The wellhead will provide support to the horizontal production tree. The wellhead and production tree will be protected by a wellhead protection structure that essentially encloses the structures. The wellhead protection structure is estimated to be approximately 10 m x 10 m as described in Section 2.3.6 of the Environmental Assessment Report (Volume 4), but its size will be confirmed during detailed design. Please refer to drawing DMEN-X00-GA-SS-15-0001 (attached) for an illustration of the well and its protection structure.	Accepted

(b) Please provide addition information as to whether traction or heavy concen-trations of suspended sands in storms have the potential for detrimental effects.	The primary issue with "traction or heavy concentrations of suspended sands in storms" is loss of foundation support (i.e. scour) for the 762 mm [30-inch] drilling conductor and the well-head protection structure. Scour is a design consideration for those structures, and therefore scour will not have a detrimental effect.	Accepted
Please provide information on potential modifications to the project proposal in terms of a safety zone or a pre-lay shellfish fishery.	The production and acid gas injection flowlines are approximately 200 mm [8-inch] and 75 mm [3-inch] in diameter respectively. The statement in Table 6.4 of the Environmental Assessment (EA) Report (Volume 4) that "a safety zone will likely be established around the flowlines (which are considered vulnerable to mobile fishing gear)" is based upon the fact that such small diameter flowlines will not likely be able to withstand an impact from mobile fishing gear without suffering any damage. Transport Canada has indicated its preliminary support for EnCana's proposed safety zone, which would exclude all fishing, around the Deep Panuke field centre (i.e., MOPU, flowlines, wellheads). The safety zone will be approximately 29.5 km2. The final boundaries of the safety zone will be determined in further consultation with Transport Canada (and other applicable regulatory agencies). The export pipeline, which will be either 560 mm [22-inch] or 510 mm [20-inch] in diameter (approximately) for the M&NP option or the SOEP Subsea Options, respectively, will be coated with concrete to reduce its buoyancy, increase its stability on the seafloor and sustain impact from conventional mobile fishing gear. As a result, no fishing restrictions are anticipated on the export pipeline, with the exception of fishing restrictions over the subsea connection to the SOEP pipeline for the SOEP Subsea Option (Section 2.4.4 of the EA Report (Volume 4)). In addition, EnCana is currently evaluating the potential risk of interaction with the hydraulic clam dredge to be used by the new Clearwater vessel, MV Atlantic Seahunter, to harvest ocean quahogs on Sable Island Bank in a fishery, which is anticipated to begin in 2007. Once this information is obtained, it will be used to determine if either export pipeline option can withstand an impact in accordance with the DNV Guideline DNV-RP-F111 "Interference between Trawlgear and Pipelines" (formally Guideline No. 13, as referenced in Section 4.9.1 of the Development Plan (Volume 2)). The necessity of fishing restrictions around the export pipeline will be confirmed during detailed design by performing a risk assessment, which will consider all potential risks to the export pipeline (including the impact of quahog dredges) in relation to pipeline burial depth, impact strength, etc. It should be clarified that, as discussed in section 2.3.5 of the EA, the 1 m trenched depth for the export pipeline is approximate and should only be considered as EnCana's preliminary design depth. This final trenched depth will be determined during the detailed engineering design phase of the Deep Panuke Project.	Accepted

(a) Please indicate whether there is a possibility that the final lay will require local bridging or route levelling through sediment filling. If so, then there would likely be an additional environmental impact on an increased footprint. Please provide information regarding the environmental assessment of these additional potential environmental effects.	(a-b) The current route design for the installation of the offshore export pipeline has been engineered to limit and, if possible, avoid the need for pre- or post-intervention activities. The route design will be reviewed by the selected pipeline installation contractor to confirm that it is acceptable and that no pre- or post-interventions are required. The area between KP22 and KP28 as illustrated by Figure 2.5 of the Environmental Assessment Report (EA) (Volume 4) is possibly the only area where pre- or post-intervention may be required. Possible intervention activities would consist of either increased weight coating, pre-lay gravel blanket for pipeline protection, local gravel berms to ensure pipeline contact with the seabed, and rock dumping or mattress placement for on-bottom stability. As part of EnCana's Environmental Effects Monitoring Plan, predicted effects will be verified and any unforeseen effects will be adaptively managed in accordance with standard EA practice and follow-up requirements.	Accepted
(b) As the engineering specifics become clearer with future and detailed planning, please indicate how the potential for as of yet unforeseen environmental affects will be assessed, including any external reviews of the assessment.	See above	Accepted

Reviewer C

Area of Expertise

Nearbed hydrodynamics, seabed stability and sediment transport processes

Documents Reviewed

1. Deep Panuke Offshore Gas Development Environmental Assessment Report. Prepared by: EnCana Corporation, November 2006; Executive Summary, Sections 1, 2, 3, 6, 7, 8, 10 and 11

Comments on the Environmental Assessment Report (November 2006)

General Comments

The above-mentioned report is, in general, well written. However, NRCan does note that in several sections the report does not provide the quantitative pipeline trenching depth to be used, and how this trenching depth was determined. The environmental assessment report (EAR) states that the pipeline will be trenched where the water depth is shallow, but fails to describe the water depth limit above which the pipeline will be trenched, and how this water depth criterion was derived. The Geological Survey of Canada-Atlantic conducted a number of studies on the nearbed hydrodynamics, sediment transport processes, bedform mobility and other geohazard for the Sable Island Bank area (see references provided at end of comments). New understandings on nearbed storm driven currents, distribution, metrics and mobility of mid- to large-size bedforms, sediment mobile layer depths caused by bedform migration, and difficult terrain conditions on the inner shelf are all relevant to the engineering design and environmental assessment of the Deep Panuke project. Publications related to these should be reviewed, with information and references added to the EAR as appropriate.

NRCan has also reviewed the Comprehensive Study Report and Development Plan Application documents contained in the 2002 application. NRCan provided some specific comments concerning nearbed hydrodynamics, sediment transport, and sediment mobile layer depth during the 2002 review. NRCan is of the understanding that previous comments were addressed at that time, and a review of the 2006 material does not demonstrate that these comments have been further address. As such, NRCan's 2002 comments thus have been revised and added at the end of NRCan's 2006 comments.

Specific Comments

Issue: Burial depth for subsea wells and flowlines; Section 2.2.2

Section 2.2.2 states that all subsea flowlines and control umbilicals of production wells will be trenched and buried.

The trenching/burial depth is an important parameter to assess the risk of pipeline exposure and spanning, due to seabed scouring and bedform migration. The section where the burial depth and justification for the selected depth are found should be cited in Section 2.2.2 if a final EAR is to be submitted.

Issue: Stability of the tie-in facility protection structure; Section 2.2.3

The report states that tie-in facility for the SOEP Subsea Option will be protected by a subsea protection structure.

Strong nearbed waves and currents and mobile sediment layers up to 1 - 1.5 m thick can affect the stability and operation of the protection structure. The proponent should indicate whether these impacts will be considered during the design of this protection structure.

Issue: Pipeline trenching and burial depth and criteria; Section 2.2.3

Section 2.2.3, p. 2-6 of the report states "The pipeline will be trenched where the water depth is shallow, as dictated by design requirements. This will also reduce span correction and reduce the potential for sediment scour to the pipeline."

While NRCan appreciates that the proponents realize that seabed scouring and sediment transport are strong on the bank top and thus pipeline will be trenched there, the proponent should also quantify to what water depth the pipeline will be trenched and how this water depth criterion was determined. Recent studies by NRCan (Li et al., 2001; King, 2002; Li et al., 2003; Li and King, 2006a) indicates that mid- to large-scale bedforms (sand waves and megaripples) can occur in water depths of up to 70 m. The migration of these bedforms can produce mobile sediment layers of up to 1-1.5 m thick. NRCan is aware that there are free span issues with the unburied segments of the SOEI pipeline (King, 2002; Li and King, 2006b). The proponent should consult SOEI and NSOPB in order to adequately determine the water depth criterion for pipeline trenching and burial.

Issue: Pipeline trenching depth and water depth criterion for trenching; Sections 2.2 and 2.3

Various sub-sections in 2.2 and 2.3 mention the routes and construction of the export pipeline, the flowlines and the umbilicals. However, it is not until section 2.3.5 that the trenching depth of 1 m is provided, without a further description as to how the trenching depth was determined. NRCan suggests that the report should acknowledge that waves, currents, sediment transport, and bedform mobility are some of the factors considered in determining if trenching will be needed and what the trenching and burial depth will be. The proponent could use section 2.3.5 as the central section to provide the pipeline trenching depth and the rational for choosing this 1 m trenching depth. Earlier or later sections should refer this section for trenching depth and rational.

Issue: Natural or mechanical burial of trenched pipeline; Sections 2.2 and 2.3

Several places mentioned that the trenched pipelines, flowlines and umbilicals will be buried either mechanically using native sediment or by natural sediment transport processes. Section 2.2.3.2 also stated "It is anticipated that the pipeline for SOEP Subsea Option will be buried."

Repeat sidescan surveys that NRCan has obtained (King, 2002; Li and King, 2006b) indicate that natural burial of trenched pipelines probably does occur, but happens gradually over a period of up to several years. The proponent should indicate whether freespan of the trenched but unburied pipeline is a safety concern. If the answer is yes, NRCan suggests that the proponent evaluate the feasibility of burying the trenched pipeline with mechanical replacement of native sediment immediately after pipeline laying.

Issue: Depth of conductors cut below the seafloor, Section 2.6

In the description of decommissioning and abandonment, the report states that the wells will be abandoned and conductors cut below the seafloor.

As sediment transport and bedform migration could cause mobile sediment layers of up to 1-1.5 m in thickness, NRCan recommends that the conductors be cut at least 1.5 m below the seafloor to eliminate possible exposure and hazards to fishing.

Issue: Cumulative effects on water quality and benthos; Sections 8.9.2, 8.9.3 and 2.7.4

Potential cumulative effects on water quality and benthos include greater suspended matter and chemical contamination. Oil and gas exploration and production in the past, present and/or future may have in turn affected or will affect water quality and benthos. The report stated "Environmental monitoring of the SOEP indicates that detectable environmental change in sediment quality and benthic communities are highly localized (under 1 km) from the platforms. Therefore, the distance between the SOEP and Deep Panuke platforms (approximately 45 km to Thebaud and 23 km to Alma) precludes spatial overlap of effects." and "It is unlikely that any adverse effects on marine benthos due to operation of the SOEP could interact cumulatively with Deep Panuke."

However, this is an assessment of the effects of drilling wastes/produced waters in the immediate vicinity of the platforms. Drilling cuttings, drill-mud minerals (barite) and other contaminants can be incorporated with the suspended load and bedload sediment, transported away from the platforms and then subsequently deposited in the deep waters around Sable Island Bank (e.g., basins, the Gully). The proponent should indicate whether there are any estimates or a monitoring plan to address the dispersion, long-term accumulation and cumulative effects of drilling wastes/produced waters to the adjacent basins and the Gully area from past, present and future oil/gas projects on Scotian Shelf.

Comments from 2002 Review:

Volume 2: Development Plan

Section 5.3 Environmental Criteria (4.3 in 2006 Development Plan)

- Bottom currents of 1.2-1.5 m/s are adequate, but wave orbital velocity can reach 2-3 m/s during storms. Has the impact of this been considered?
- Seabed scours and sediment mobile layer depth caused by sediment transport and bedform mobility are critical to pipeline and flowline trenching depth and the scour depth estimates for MOPU operation, thus should be included in the environmental design criteria for pipeline and MOPU (section 4.3, tables 4.1 and 4.2 in 2006 Development Plan).

Volume 4: Environmental Impact Statement

Section 5.1.3.2

- Peak tidal current of 25 cm/s seems low; they should be 30-35 cm/s, occasionally reach 40 cm/s (Li et al., 1997; Li et al., 1999a).
- There is new knowledge on nearbed currents during storms: measurements and modeling show that they are 50 - 75 cm/s during typical storms (Amos and Judge, 1991; Li et al., 1997; Li et al., 1999a).

Section 5.1.6.4

- The concept of low energy in E zone near Northern Spur is out dated. Modelling and field data suggest that strong wave oscillation and wind-driven currents and sheet flow transport can occur in this zone during winter storms (Amos and Judge, 1991; Li et al., 1997; Li et al., 1999a). This implies that seabed instability due to sediment transport and bedform migration should be a concern for the Encana pipeline on the northwestern Sable Island Bank.
- Table 5.13 and associated text: Substantial new knowledge has been obtained about bedforms and their mobility on Scotian Shelf (Li et al., 1999b; Li et al., 2001; King, 2002; Li et al., 2003). The following revisions are suggested:
  - Sand ridge: Add that sand waves and mega-ripples can be superposed on sand ridges.
  - Add large wave ripples (LWR) row: A sharp, liner-crested, flow-tranverse bedforms composed of medium to coarse sand, formed by wave oscillation during storms. Often occur in the troughs of sand ridges, sand waves, and megaripples. Average height 5 - 50 cm; average wavelength 1-3 m.

Section 5.1.6.5

- This section is not up to date:
  - Field measurements and model predictions have shown that the non-linear interaction between waves and currents significantly enhance bed shear stress, bed roughness and sediment transport on Scotian Shelf. (Li et al., 1997).
  - Sheet-flow transport over sand has been observed in 60 m depth during storms. (Li and Amos, 1999).
  - Repetitive multibeam and sidescan surveys have indicated that sand ridges are moribund and only migrate during major storms. Their migration rate is low (mean rate < 5 m/year) and to opposite directions in short time periods. Mean migration averaged over longer times (several years) is insignificant. But sand waves, megaripples and large wave ripples are mobile during typical storms and their migration can provide mobile sediment layers up to 1-1.5 m thick (Li et al., 1999b; Li et al., 2001; King, 2002; Li et al., 2003; Li and King, 2006a).

Section 6.2.4.1

- Drilling Activities: Wind-driven currents during storms can also be aligned with, and hence enhance, tidal currents to significantly increase the size of the deposition base of the cuttings piles.

Section 7 Effects of the Environment on the Project

- Effects of waves and currents should be discussed as well in this section.

7.7 Sediment Transport and Seabed Stability

- Impacts due to mobile sediment layer caused by bedform migration and seabed scouring from flow-structure interaction should be critical to project design.
- Maximum mobile layer depth should be estimated along pipeline route to determine where trenching/burial is needed and what trenching/burial depth is required.

10 Summary and Conclusions

- Impacts of the environment on the project should be included in this discussion.

References

Amos, C.L. and Judge, J.T., 1991. Sediment transport on the eastern Canadian continental shelf. Cont. Shelf Res., 11: 1073-1068.

King, E.L., 2002. Sable Island Bank shallow geological conditions: Geohazard atlas and catalogue compiled from shallow reflection seismic data. Unpublished Final report to Sable Offshore Energy Incorporated, Halifax, Nova Scotia, by the Geological Survey of Canada.

Li, M.Z. and Amos, C.L., 1999. Field observations of bedforms and sediment transport thresholds of fine sand under combined waves and currents. Marine Geology, 158: 147-160.

Li, M.Z. and King, E.L., 2006a. Seabed Disturbance and Sediment Mobility on the Storm-Dominated Sable Island Bank, Scotian Shelf. Abstract in proceedings of 17th International Sedimentology Congress, Aug. 28 - Sep. 1, 2006, Fukuoka, Japan.

LI, M.Z. and King, E.L., 2006b. Hudson 2004037 Cruise Report: Geohazards in the Sable Island Bank Area, Scotian Shelf. GSC Open File 5077, 117 p.

Li, M.Z., Amos, C.L. and Heffler, D.E., 1997. Boundary layer dynamics and sediment transport under storm and non-storm conditions on the Scotian shelf. Marine Geology, 141: 157-181.

Li, M.Z., Amos, C.L., and Heffler, D.E., 1999a. Hydrodynamics and Seabed Stability Observations on Sable Island Bank: A Summary of the Data for 1996/97. Geological Survey of Canada Open File Report 2997.

Li, M.Z., Currie, R., Beaver, D., Gerard, P., and Pledge, P., 1999b. Multibeam Surveys of Sable Island Bank and the Gully Area of Scotian Shelf: Report on Creed Cruise 98-100. GSCA Internal Cruise Report, 44 p.

Li, M. Z., King, E. and cruise participants, 2001. CSS Hudson Cruise 20000-30a: A Geological and Geophysical Survey on Sable Island Bank and Scotian Shelf. Geological Survey of Canada Open File 4000, 50 pp.

Li, M.Z., King, E.L. and Smyth, C., 2003. Morphology and Stability of Sand Ridges on Sable Island Bank, Scotian Shelf. GSCA Open File 1836, 52 pp.