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March 17, 2003 022-2552-6035

Mackenzie Valley Environmental Impact Review Board
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Attention: Alan Ehrlich, A/Manager of Environmental Impact Assessment

RE: WesternGeco Mackenzie River 2D Seismic Development Deficiency Statement

Dear Alan:

In response to your letter of March 4, 2003 noting deficiencies in WesternGeco's Environmental Assessment Report for the above proposed development, we are providing responses to the stated deficiencies as noted below.

Terms of Reference Section 4.3-Development Description

"WG shall include a thorough Development description that includes...expected channel depths".

Response:

WesternGeco's proposed program was designed to be carried out in the deepest parts of the Mackenzie and Liard rivers. Expected depths for the Mackenzie River were obtained from nautical charts and through information gathered from NTCL pilots. This information, along with fathometer readings observed during the 2002 testing program, verify estimates for those portions of the river. As noted in the EA (Hydrology, Section 3.3.1), the 2002 Test

Program operated in channel depths ranging from 7 metres to 32 metres.

Depths for the Mackenzie River are expected to be at least 1 metre deeper than the approximately 2.5 meter depth at which seismic equipment will be towed. Exceptions to this may be at the Ramparts (Reference Canadian Hydrographic Service, Mackenzie River Charts 6421 and 6422); San Saults Rapids (Reference Canadian Hydrographic Service, Mackenzie River Chart 6420), where a narrow passage and high currents are present; and the bend just north of the Black River (Reference Canadian Hydrographic Service, Mackenzie River Chart 6415), where shallow depths are recorded between the two narrow channels. In these locations, the environmental scout vessel, taking depth readings, will be leading the recording vessel at a distance such that depth changes are reported and seismic gear hauled in if necessary.

Charted river depths are reduced to low water chart datum that corresponds to reference points along the river. For example, low water chart datum at Norman Wells occurs when the water surface is at 3.4 metres above zero at the Water Survey of Canada gauge at that location. As stated on the Charts for the Mackenzie River, during the navigation season the river depths can increase 3.0 metres above charted depth readings at Inuvik to 7.5 metres above charted depth readings at Fort Good Hope. Using these figures, the expected water depths will range from 4.0 to 27.5 metres along the length of the river from Inuvik to Fort Simpson.

The Liard River is an uncharted waterway; there are no marine charts or navigation aids for this area. Vessels operating along this river depend on local knowledge to navigate the channels. The Cooper Barge Company and NTCL are good sources of local knowledge, and information obtained from them regarding channel depths was positive. The main known shallow portion of the Liard River occurs over a 24 km section starting near the junction of the Birch River, and ending at a shelf in the river known as the Beaver Dam. As with the Mackenzie River portion, the scouting vessel will be taking depth readings, and will be able to report back to the recording vessel, allowing seismic gear to be hauled in if necessary. This may need to occur at the Beaver Dam area mentioned.

"WG shall include a thorough Development description that includes...types and amounts of hazardous materials stored on the barge".

Response:

A list of maximum quantities of petroleum oils and lubricants that would be stored on board the M.V. Henry C. as part of that vessel's regular operating equipment was provided in Appendix IX of the EA (Emergency Response Plan and Oil Spill Contingency Plan - page 29, revision 1, Section III of the Oil Spill Contingency Plan for the M.V. Henry C.). In addition to that list, WesternGeco will be providing quantities of several substances (antifreeze, diesel fuel, engine oil and hydraulic oil) which will be used by both WesternGeco and NTCL. These are shown below.

As described in Section 12 of the EA, the only additional hazardous materials that WesternGeco will have on the vessel strictly for the operation of seismic equipment will be kerosene (ISOPAR M) and lithium batteries. We now estimate a greater quantity of ISOPAR M will be required (208 litres vs about 90 litres or 24 gallons identified in the EA Report). For greater clarity, we are also identifying separately a quantity of synthetic compressor oil, which is a type of engine oil and was previously considered to be included where reference to engine oil was made.

In summary, the following hazardous materials would be *in addition to* those listed in the Oil Spill Contingency Plan for the Henry C.

Hazardous Material	Amount
Materials Common to WesternGeco and NTCL:	
Antifreeze	1 drum (208 litre)
Diesel fuel	150 m^3
Engine oils (Chevron delo 400 30 wt)	1 drum (208 litre)
Hydraulic oil (EAL 224H)	1 drum (208 litre)
Materials Unique to WesternGeco's Proposed Seismic Program:	
Lithium batteries	100
Cable oil (ISOPAR M)	1 drum (208 litre)
Synthetic compressor oil (Rarus 827)	1 drum (208 litre)

Terms of Reference Section 4.8-Noise

"WG to report results from acoustic field studies undertaken during 2002...this discussion should also evaluate the importance of substrate type..."

Response:

This question was addressed in the EA (Acoustic Field Studies Report – Appendix II) with respect to water depth, channel width and channel bank steepness. The influence of river-bed substrate was not addressed directly, so a discussion of its potential influence is included below.

The river-bed substrates, though not sampled directly, are believed to consist mainly of sands and gravels over much of the course of the river. The water flow washes finer grained materials downstream to the Delta. Visual observations of the sands and gravels on the shores of the river indicated that they appeared to be fairly consistent between the sites at which the monitoring program was carried out. However, it may be expected that grain size could be relatively smaller in sections of river having slower currents. It is known that the sediment grain size is significantly less in the slow-flowing channels in the Delta.

Differences in the rate of sound attenuation with distance were attributed mainly to the water depth along the sound propagation paths over which measurements were made. In fact, local variations in water depth were directly correlated with fairly large changes in the rate of sound attenuation. The analyses of measured pressure waveforms identified several instances of sound reflections off the river's banks at locations with steeper banks. These reflected signals had relatively low amplitudes, and were of secondary importance insofar as their contributions to the overall received sound levels at distance.

The analyses did not attribute noticeable differences in the rate of sound attenuation to different substrate types. This may have been due to the relatively consistent substrates present at the three sites monitored. However substrate type can be expected to have some influence on sound attenuation rates. The sands and gravels present over much of the river have relatively high reflection coefficients relative to those for finer-grained sediments such as silts, muds and clays. Reflection coefficients for sands are approximately 0.2-0.3 at normal incidence, while those for fine grained muds and clays are approximately 0.05 – 0.15 (Hamilton, 1980). Furthermore sands have lower attenuation coefficients than silts, muds and clays. It is noted that fine-grained silts, muds and clays often form the bottom substrate of non-flowing or slow-flowing bodies of water.

The measurement program clearly showed that the sound field in the river is dominated by modal sound propagation. The ability of the river to support modes is dependent on the near-grazing reflection coefficients of the bottom substrate. These reflection coefficients are primarily dictated by the substrate's sound speed, which defines the critical reflection angle at which modal sound energy will reflect with no loss, i.e. with a reflection coefficient of 1. This critical angle increases with increasing sound speeds, so a greater number of water-borne modes can be supported with higher substrate sound speed. Furthermore the relatively low attenuation coefficients of sands, with respect to those for silts and clays, will have influence on the modes that travel partially in the river-bed sediments. These modes will attenuate more quickly with higher substrate attenuation coefficients.

We note that the sands and gravels present at the monitoring sites have relatively high sound speeds and reflection coefficients, and relatively low attenuation coefficients. These sediments are conducive to supporting modal sound propagation. Slower flowing sections of river, such as those in the Delta, can be expected to have substrates consisting of finer-grained sediments having lower sound speeds. These sediments would be less-able to support strong modal propagation, and consequently the rate of sound attenuation for similar water depths is expected to be greater than the rates measured at the monitoring locations.

Reference

Hamilton, E.L. 1980. Geoacoustic Modelling of the Sea Floor. J. Acoust. Soc. Am. Vol. 68, p. 1313-1340.

Terms of Reference Section 4.9-Aquatic Resources

"This section shall include a discussion of...potential impacts of airguns on...eggs and larvae, of fish species that are likely to be present in the Liard and Mackenzie Rivers...with respect to the size airguns to be used during the proposed development."

Response:

Information on the potential impacts of airguns on fish eggs and larvae for species likely to be present in the Mackenzie and Liard rivers was presented in Section 9.2.2.1, p. 113 of the EA. Report. Details of the size of airguns to be used during the proposed development were provided in Section 3.2.3.1, p. 14-15, and Appendix II (Acoustic Field Studies Report).

There is little to no information available for the effects of airgun seismic activity on freshwater fish eggs, larvae, or adults. In particular, no information is available on the potential impacts of airguns on eggs and larvae of fish species that are likely to be present in the Liard and Mackenzie Rivers. All research has been conducted on marine species, and these results are presented and discussed in the EA.

The size of the airgun array to be used by WesternGeco is 1500 in^3. The array will be composed of two 750 in^3 subarrays that operate at an air pressure of 2,000 PSI and the guns will fire approximately every 9 seconds. The maximum sound levels measured in the near field were 224 dB re Pa (peak) and 213 dB re Pa (RMS, root mean squared) at 4m from the array as it was operated in the Mackenzie River, 2002. These values scale to a source level of 236 dB re Pa at 1m (peak) and 225 dB re Pa at 1m (RMS) for the airgun array (Appendix II).

It is important to note that the energy sources in the studies referenced below and in the EA were different than the array being used by WesternGeco; transference of referenced study results to conditions in the Mackenzie River by operating pressure alone is an over simplification.

For marine species, the lethal radius for eggs and larvae when exposed to airguns was reported as between 0 - 3 m, and signals > 230 dB were necessary for harm to occur (Kostyuchenko 1973 and Gausland 2000). Yolk sac larvae (2 days old) have been found to be sensitive to the release of seismic energy at distances < 3 m.

For this proposed development, the seismic vessels will follow the route used by commercial barge traffic (the thalweg of the river). The thalweg of the Mackenzie River is not suitable for the spawning and early life development of most endemic fish species because of the river's depth, turbidity, velocity and substrate. Fish eggs or larvae in the Mackenzie River watershed, therefore, are expected to be most abundant in tributaries or lakes where fishes spawn, and not common in the thalweg. If eggs and larvae are present in the thalweg, however, they will only encounter source levels that have been found to cause harm (>230 dB) up to approximately 1.5 m from the airgun array.

"This section shall include a discussion of...potential short and long-term effects of airguns on invertebrates that are, directly or indirectly, ecologically linked to fish...with respect to the size airguns to be used during the proposed development."

Response:

Information on invertebrates was provided in Sections 8.4 and 9.2.5 of the EA.

There is little to no information available for the short or long-term effects of airgun seismic activities on marine invertebrates, and no information could be found for the effects of airgun seismic on freshwater invertebrates. Therefore, no information is available on the potential impacts of airguns on invertebrate species that are likely to be present in the Liard and Mackenzie Rivers. The analysis provided in the EA (Section 9.2.5), concerns potential short-term effects, as judged from studies with marine invertebrates.

It is predicted in the EA that the rigid exoskeleton and lack of a gas filled organ in invertebrates likely provides protection from airgun insonification. The seismic survey will be travelling in the thalweg, with the airgun array suspended at approximately 2.5 m below the river surface. A residual impact is only predicted in the unlikely event that the airguns are accidentally grounded, and habitat for benthic invertebrates is directly contacted and disturbed.

"This section shall include a discussion of details of mitigation measures...including...ramping up procedures...This discussion is also to include a description of all uncertainties related to the above."

Response:

A summary of mitigation measures is provided in Section 11 and in Table 11-1 of the EA.

Mitigation measures include:

- Towing the airgun array through the deepest part of the river channel and at a depth of 2.5 m. Results from the 2002 Fish Field Studies indicate that most fish are located in the deepest part of the thalweg and not near the airgun array at the river's surface (Section 3.2.3; Appendix III).

- There will be operational shutdowns when the airgun array will be silent (Sections 9.2.2.2, 11).

- Starting the program before annual fall migrations of anadromous fish species and after juvenile dispersal in the spring (Sections 3.3.4, 5.1.4, 8.2, 9.2.2.2, 10.3.1). Wright (2002) suggested that the avoidance of important periods for migration was among the most important mitigation techniques.

- The ramping up procedure will be conducted during start-up that follows every shut down, which will allow fish to move away from the source before it reaches full capacity (Sections 3.2.4, 8.2.1.1). However, horizontal and vertical scanning of waters by hydroacoustics, 2002, showed that there were few fish near the surface of the water and that there was no clear avoidance reaction to discharge of the airgun array. Ramping up will continue to be used though, as a precautionary measure.

- Monitors will be employed to survey for dead or injured fish. If 10 or more stunned fish are observed within one hour, or any dead fish, are observed in the wake of the Project, the Project will be suspended pending discussions with DFO (Section 11). In the 2002 Test Program, no dead or injured fish attributable to the airgun array were observed, and none are expected for 2003.

- The source will be pulsed, not continuous, and will only pass through any area on the Mackenzie once (Sections 3.2.4, 11). Thus, exposure of aquatic organisms is minimized and exposure, therefore, will be considerably less than the prolonged exposure times cited in the literature as producing effects.

- The uncertainty related to all specific impact analyses is reported as a confidence level in the prediction (Section 9; Appendix VIII).

"This section shall include a discussion of...general hearing information (bandwidth and thresholds) on Mackenzie River fish or related <u>species</u> (at all life stages) for which data are available in the literature".

Response:

Hearing information for fish is summarized in Section 9.2.2.1, p. 110 – 111 of the EA.

Popper and Fay (1993) indicate that the anatomic and physiologic variation among fishes is great and that various species may detect and process sound in different ways. There is little to no information available for the hearing abilities of freshwater fish. Therefore, no information is available on the hearing abilities (bandwidth and thresholds) of fish species endemic to the Liard and Mackenzie Rivers.

Most research on fish hearing has been conducted on marine species, and that information is not necessarily applicable to freshwater fish. However, some research on freshwater species related to species endemic to the Mackenzie River has been conducted, and some generalizations have been drawn. Fish belonging to the minnow family have specialized hearing adaptations that should detect a great range of noise levels and frequencies (McPhail and Lindsay 1970; Popper and Fay 1973; Stewart 2001). Hearing in salmon, and probably the subfamily Coregoninae that are common in the Mackenzie River, is restricted to frequencies below about 380 Hz, with greatest sound detection at frequencies below 150 Hz (Hawkins and Johnstone 1978; Knudsen et al. 1992); therefore, salmonids are classified as hearing non-specialists. Generally, hearing specialists detect sound pressure with greater sensitivity (as low as 55 dB re 1 µPa) and in a wider bandwidth (to 3 kHz) than non-specialists (Popper and Fay 1993).

No information about hearing in early life stages of freshwater fish endemic to the Mackenzie River is available. However, we assume that the rudimentary auditory vesicle in a typical teleost fish larva evolves into the species specific components that form the hearing apparati once the larva assumes its juvenile form (Kelso and Rutherford 1996). In the juvenile stage (for walleye, as an example, this will occur in early autumn of the first year of life), fish assume the adult body form and function.

A review of Higgs et al. (2003) has taken place since the EA was submitted. Higgs et al. (2003) report that the development of form and function in auditory structures likely varies among species because of variable, but often prolonged, post-hatching development and diversity of auditory specializations. For example, no change in auditory sensitivity with growth has been found in the juvenile and adult stages of goldfish (Popper 1971 *cited in* Higgs et al. 2003), while damselfish have large increases in auditory sensitivity over the range of detectable frequencies (Kenyon 1996 *cited in* Higgs et al. 2003). Higgs et al. (Higgs et al. 2002a *cited in* Higgs et al. 2003) found that sensory hair cell development increased with zebrafish growth. As well, Higgs et al. (2003) found that for zebrafish, a hearing specialist, an expansion of maximum detectable frequency occurred from 10 to 45mm and suggested that changes in hearing ability is likely driven by development of auxiliary hearing specializations rather than changes in the ear itself.

New Reference:

Higgs, D.M., A.K. Rollo, M.J. Souza and A.N. Popper. 2003. Development of form and function in peripheral auditory structures of the zebrafish (*Danio rerio*). J. Acoust. Soc. Am. 113(2): 1145-1154.

"This section shall include a discussion of...potential impacts of airguns on anatomy and physiology of fish exposed to airguns (including effects on ear, lateral line, swim bladder and any other stress indicators)".

Response:

Information on potential impacts of airguns on the anatomy and physiology of fish is provided in Sections 8.2.1.2, 9.2.2, 10.3.1, and Appendix III of the EA.

There is little to no peer reviewed information available concerning the potential impacts of airguns on anatomy and physiology of fish exposed to airguns. However, the Caged Fish studies conducted in 2002 (Appendix III) showed that none of the fish that were sacrificed for histopathology had any abnormalities attributable to airgun exposure i.e. no ruptured swim bladders, no noticeable haemorrhage, and no gross physiological damage to the inner ear as examined. In the EA (Impacts on Fish Hearing-page 112) there is a discussion of recent fish hearing studies linked to Popper's laboratory and available on Popper's website. That work was subsequently published as: McCauley, R.D., J. Fewtrell and A.N. Popper. 2002. High intensity anthropogenic sound damages fish ears. J. Acoust. Soc. Am. 113(1).

McCauley et al. (2000) took blood samples from a variety of marine fish (silver bream, pink snapper, trevally, mullet and herring) exposed to airguns and in control conditions to monitor their stress response to nearby airgun operations. Blood plasma glucose (secondary stress indicator) and/or cortisol (primary stress hormone) levels were measured. Stress measurements showed no significant increases which could be definitively associated with airgun exposure (McCauley et al. 2000).

No information could be located concerning the potential impacts of airguns on the lateral line of fishes.

"This section shall include a discussion of...long-term impacts <u>over days, weeks, and months, and implications for</u> survival of exposed fish...with respect to the size airguns to be used during the proposed development".

Response:

Information on the potential long-term impacts is provided in Section 10.3.1, and Appendix III of the EA.

McCauley et al. (2000) report that the normal behavioural pattern of marine fish, tested in a caged fish trial, resumed between 4-31 minutes after the cessation of airgun activities. A behavioral response by fish (e.g., herding, altered distribution in the water column, change in catch by extant fisheries) in the Mackenzie River was not detected during the 2002 test study and, when a response was reported in the literature (i.e., change in catch rate or response of fish caged near airguns), that response was of short (minutes for behavioural cage tests and days for change in marine catch rates for some fish species) duration.

Engas et al. (1996) reported depressed catch rates of cod and haddock following seismic surveys. Abundance and catch rates did not return to preshooting levels during the 50 day period after seismic shooting ended. Conversely, Lokkeborg and Soldal (1993) indicated that catch rates might increase in an area exposed to seismic vessels if deep water trawls were used. Dalen and Knutsen (1987) used hydroacoustics as did the 2002 Test Program and also indicated that fish distributions are naturally variable and that there was no statistically significant effect of the airgun seismic survey upon distributions of fish. Consequently, studies are inconclusive and somewhat conflicting regarding effects on fish behaviour and catch rates. Long term (i.e. days) impacts on fish in the Mackenzie are unlikely, as community members along the Mackenzie did not report any abnormalities in their catch rates after the 2002 test.

Impacts on anadromous fish in the Mackenzie and Liard rivers are possible, but unlikely. Operations in the Mackenzie Valley will commence at the Inuvialuit/Gwich'in border and proceed in a southerly direction. This will minimize impacts on migrating species, which predominantly start their migrations in August/September.

Considering the mitigation strategies proposed (e.g., scheduling, ramp up, monitoring), and the results of the 2002 Fish Studies (Appendix III) combined with results available in the literature, it is predicted that any resultant cumulative effect related to impacts to fish would be of low significance.

Documented effects of airgun operation, particularly airguns of the size proposed for use in this project, are few and apparently none of those reported effects were statistically significant. Therefore, the likelihood of immediate and direct damage is considered to be low for the more sensitive early fish life stages of fish because eggs remain in streams until larvae emerge and are transported downstream. Those, apparently less sensitive, larval and juvenile forms that are near the river's surface are exposed briefly, and mortality is expected to be of low significance in the freshwater environment, as in marine systems (Davis et al. 1998).

We trust that this information addresses the deficiencies you have documented.

Yours very truly,

WESTERNGECO

Keith Rosindell