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Re: Comment on Pacific Northwest LNG Environmental Impact Statement and Environmental Assessment Certificate Application (Project # 1231-10537)

To whom it may concern,

I was asked to provide general comments on the Pacific Northwest LNG (PNW LNG) Environmental Impact Statement (EIS) and Environmental Assessment Certificate Application (Project # 1231-10537) on behalf of the T. Buck Suzuki Environmental Foundation in Prince Rupert, British Columbia (BC). This EIS is for the construction and operation a liquefied natural gas (LNG) facility on Lelu Island near Prince Rupert. I have focused my concerns on the potential impacts on freshwater ecosystems of atmospheric acid deposition from this potential project combined with the cumulative atmospheric emissions from other current and proposed LNG operations and other industries in northwestern BC.

I received my PhD in 2013 with a specialization in aquatic ecology from the University of Alberta in the Department of Biological Sciences where I am currently working as a postdoctoral researcher with Dr. Rolf Vinebrooke. I have worked in the field of aquatic ecology since 1997 during my BSc, MSc, PhD, and current postdoctoral studies (Bunting et al. 2010, Hobbs et al. 2010, Weidman et al. 2011, 2014). During this time, I have also worked as an aquatic ecologist at the Experimental Lakes Area (ELA; Fisheries and Ocean Canada) in northwestern Ontario on projects including whole-lake acidification experiments (Weidman et al. 1998, Donahue et al. 2001). I have also worked at the Ontario Ministry of Environment in Etobicoke, Ontario, on nutrient pollution issues in the Laurentian Great Lakes (Weidman and Howell 2005).

First, I would like to summarize my general concerns regarding increased acid deposition and freshwater ecosystems in northwestern BC, which I will expand upon below in more detail. Over the next several decades, there is large potential for increased atmospheric emissions of acid-forming sulphur and nitrogen from proposed liquefied natural gas (LNG) facilities in northwestern BC (Knox 2013). **Coastal lakes and watersheds in northwestern BC are**

situated in some of the most acid-sensitive geological regions of Canada (Kalff 2002). Low pH and low acid neutralizing capacity (ANC) of lakes in this region make them very sensitive to acid deposition (Swain 1987). Acid neutralizing capacity of lakes with low alkalinity, which is a measure of ANC, can be controlled largely by microbial processes at the sediment-water interface instead of terrestrial inputs (Kelly *et al.* 1987). Biological sources of alkalinity are inherently more variable and specific to internal lake conditions, such as reduction-oxidation potential in sediments. Lake catchment characteristics can also be very specific, with some terrestrial catchments acting as sources or sinks of alkalinity (Schindler 1986). Complex interactions among multiple stressors including acidification, drought, and climate warming will further complicate predictions of single stressor effects on aquatic ecosystems (Christensen et al. 2006, Weidman et al. 2014). As a result, provincial objectives for atmospheric acid deposition may not be conservative or specific enough to local lake and catchment characteristics to protect freshwater ecosystems in this region from the potential of increased acid deposition.

The current PNW LNG EIS only assesses impacts of acid deposition from the proposed project and current industrial emissions near Prince Rupert. There are three LNG facilities that are currently going through the Canadian Environmental Assessment Agency process ([CEEA] 2014). There is a total of six LNG facilities under consideration in the Prince Rupert area (Government of British Columbia 2014). Thus, one of my major recommendations is that the BC Ministry of Environment should consider a comprehensive strategy for assessing the sensitivity of freshwater ecosystems to cumulative acid deposition from all proposed LNG facilities in northwestern BC.

Acid Deposition in Northwestern BC from LNG facilities will be Unprecedentedly High

Development of liquefied natural gas (LNG) facilities in northwestern BC will greatly increase atmospheric emissions of sulphur and nitrogen, which form strong acids in precipitation and aquatic environments. In Kitimat (BC), for example, three proposed LNG facilities are expected to increase current industrial and municipal emissions of sulphur dioxide (SO_4) and nitrogen oxides (NO and NO_2; collectively denoted as NO_x) by 157% and 588%, respectively, which is equal to 9,482 tonnes $SO_4 \cdot y^{-1}$ and 16,949 tonnes $NO_x \cdot y^{-1}$ (Knox 2013 and references therein). These emissions would be 2.5x greater than all emissions from the metro Vancouver region and would be equivalent to 60% of all annual acid emissions for the province (Knox 2013). Put another way, projected levels of atmospheric acid emissions near Kitimat represent about 10% of current acid emissions from the entire oil sands operation in northern Alberta, which equal about 220,000 tonnes of S and N combined per year (Hazewinkel et al. 2008 and references therein). These emissions levels do not include a fourth potential LNG facility at Kitimat. There are currently 12 LNG facilities that are proposed or under consideration in northwestern BC (Government of British Columbia 2014).

Acid deposition continues to damage aquatic ecosystems in Canada. In vast regions of eastern Canada acid deposition still exceeds the capacity of catchments to neutralize this acidity (i.e., critical acid load exceedance), which delays recovery of lakes and watersheds from long-term acidification (Schindler and Lee 2010). Moreover, in the Fraser River Valley BC, critical acid loads have already exceeded the capacity of the Lower Fraser River watershed to neutralize acidity (Carou *et al.* 2008). Catchments in this region can neutralize acid deposition up to 400–1000 $eq \cdot ha^{-1} \cdot y^{-1}$, but critical acid loadings already exceed this threshold by more than 1000 $eq \cdot ha^{-1} \cdot y^{-1}$ in a region up to 150 km east of Vancouver. Thus, acid deposition in northwestern BC will likely impact lake food webs in more acid-sensitive catchments if emissions increase beyond the levels in the Lower Mainland.

Lakes in Northwestern BC are Highly Acid-Sensitive

Lakes in coastal regions of northwestern BC tend to be acid-sensitive because they are situated in catchments comprised of non-soluble bedrock and soils (Kalff 2002). For example, local geomorphology near Prince Rupert is characterized by alpine and glacial landforms comprised of non-soluble materials such as schist, gneiss, and quartzite (Hutchison et al. 1973, Fulton 1995). Approximately 25% of 752 lakes sampled throughout BC have pH < 7 and may be considered highly sensitive to acid deposition (Swain 1987); five of the top 10 most acid-sensitive lakes (pH < 6) in BC are located near Prince Rupert. Changes in aquatic food webs due to acidification are generally apparent below pH 6, including a linear decline in the number of fish species that are able to survive with decreasing pH (Matuszek and Beggs 1988). Thus, lakes in this region are highly sensitive to acid inputs.

Acid neutralizing capacity becomes difficult to predict in lakes with very low alkalinity for a variety of reasons. Lakes that are very low in alkalinity may be dominated by internal biological alkalinity generation and not by terrestrial inputs (Kelly *et al.* 1987). As a result, ANC can be lake-specific, where lakes with low water residence time and high hypolimnetic oxygen are the most sensitive to acidification. Indeed, low water residence times (mean: 1.4 y, range: 0.9–3.0 y) and oxic hypolimnetic conditions are characteristics of coastal lakes in northwestern BC (Shortreed et al. 2001, 2007). In acid-sensitive boreal lakes in northwestern Ontario, terrestrial catchments can act as either sources or sinks of alkalinity, which further complicates determination of ANC (Schindler 1986). Further, small additions of acidity result in exponential decreases in pH between 5.5 and 6.5 due to the shape of the acid-titration curve (Henriksen 1980). Critical acid loads for catchments near Prince Rupert are low (< 150 eq·ha^{-1}·y^{-1}), reflecting their high degree of acid-sensitivity (Carou *et al.* 2008). Thus, small errors in atmospheric models and calculations of acid deposition may result in potentially large ecological effects of increased acidity on biota in acid-sensitive lakes.

Alwyn Lake is the drinking water reservoir for Port Edward District near Prince Rupert and would receive acid deposition from the proposed Pacific NW LNG facility on Lelu Island. Consequently, this lake was the focus of a study of the effects of LNG acid deposition ([PNW LNG] 2014). Alwyn Lake is among only 5% of lakes in BC with < 5 mg total alkalinity (Swain 1987). Lake pH was highly variable, ranging from 5.8 to 7.3 pH among monthly samples from 2010–2013. This further illustrates how difficult it may be to predict the impacts of acid deposition on highly sensitive lakes in this region due to lake- and catchment-specific variability.

Multiple Stressors, Cumulative Effects and Ecological Surprises

Environmental science is replete with examples of impacts of multiple stressors on ecosystems (Ormerod *et al.* 2010), which can have cumulative effects and complex interactions that are difficult to predict (Weidman *et al.* 2014), These interactions are sometimes referred to as “ecological surprises” (Christensen *et al.* 2006). In whole-lake acidification experiments in northwestern Ontario, several effects on aquatic food webs were not predicted by small-scale experiments and synoptic surveys (Schindler *et al.* 1985); these unexpected effects included 1) proliferation of filamentous green algae (mainly *Mogeoutia* spp.) in littoral regions, 2) collapse of crayfish (*Orconectes virilis*) populations due to acid-induced stress and fungal infections, 3) collapse and replacement of the fathead minnow (*Pimephales promelas*) with the pearl dace minnow (*Semotilus margarita*), and 4) collapse of lake trout (*Salvelinus namaycush*) due to multiple trophic effects and not direct effects of acidity and metal toxicity. In eastern Canada, the combination of continued exceedance of critical acid loads and acid pulses to lakes following periods of drought have combined to delay the recovery of lakes from acidification (Keller et al. 2007, Schindler and Lee 2010). In more productive lakes in Alberta, acid deposition from oil sands extraction appears to have unexpectedly stimulated internal phosphorus loading and primary productivity via competitive binding of iron and sulphate, which can stimulate phosphorus release from sediments (Hazewinkel *et al.* 2008). Thus, the ecological effects of acid deposition on lake food webs and their productive capacity and ability to support fish populations will be difficult to predict from synoptic surveys and the expected effects of single stressors alone.

Conclusions and Recommendations

The consideration of the potential acid impacts of from LNG facilities near Prince Rupert is scientifically insufficient as a result of the complications raised above. My main concern is that provincial objectives for atmospheric acid deposition may not be conservative or specific enough to local lake and catchment characteristics to protect freshwater ecosystems from the cumulative impacts of increased acid deposition from all proposed LNG development. My main recommendation is that the BC Ministry of Environment should consider a comprehensive strategy for assessing the sensitivity of freshwater ecosystems and fish populations to cumulative acid emissions from all proposed LNG facilities in northwestern BC.

I also have several specific recommendations that would also help address the potential uncertainties regarding impacts of increased acid deposition in northwestern BC.

1) The potential long-term cumulative impacts of acid deposition on freshwater environments should be assessed. This could be achieved by spatial mapping of decadal-scale (not just annual) acid deposition on the watersheds surrounding the proposed LNG facilities, including Prince Rupert, Kitimat, and Grassy Point. This would facilitate the calculation of cumulative impacts on freshwater and terrestrial environments from acid deposition in several scenarios (best-case to worst-case) on a decadal scale for next 50 years. This effort would also help identify the most sensitive freshwater habitats and salmon populations (e.g., sockeye salmon, pink salmon, chum salmon, chinook salmon, coho salmon) and trout populations (e.g., rainbow trout, brook trout, cutthroat trout) that may be impacted by the cumulative acid deposition from all proposed LNG facilities in each airshed.

2) A sensitivity analysis should be conducted on the steady state water quality models used by the proponents in the PNW LNG EIS to calculate critical acid loads for lakes affected by acid deposition. This study should be expanded to include lakes and streams identified as sensitive to long-term cumulative impacts of acid deposition. These further efforts would help resolve potential uncertainties in the impacts of acid deposition on lakes due to lake- and catchment-specific variation in acid neutralizing capacity.

3) The cumulative and interactive effects of acidification and warming and drought resulting from climate change on lake food webs and the production and condition of juvenile sockeye populations should be tested in large-scale mesocosm experiments. This additional study would help resolve the potential interactions among these multiple stressors on salmon and trout populations in the region (Wright and Schindler 1995, Christensen et al. 2006).

4) The results of these additional studies should be tested scientifically through submission to well-ranked peer-reviewed journals.

5) The proponents should be required to conduct a cost-benefit analysis of the proposed and all potentially available technologies for reducing total atmospheric acid emissions (Esplin 2014). This should include consideration of electronic-drive compression for liquefaction of natural gas, which would greatly reduce natural gas combustion in the liquefaction process (Knox 2013).

In closing, I would like to emphasize two main points. First, potential atmospheric acid deposition in northwestern BC is unprecedented in scale given proposed development of LNG facilities. Second, catchments and lakes in this region of BC are extremely sensitive. For these reasons, acid emissions could damage ecosystems, fish that support fisheries, air quality, and water quality.

Thank you for considering my concerns and suggestions on this matter. Please let me know if I can provide any additional information.

Sincerely,

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References

[CEEA]. 2014. Canadian Environmental Assessment Registry. [CEEA] Canadian Environmental Assessment Agency. Available from http://www.ceaa-acee.gc.ca/050/index-eng.cfm [accessed 30 April 2014].

[PNW LNG]. 2014. Environmental Impact Statement - Liquefied natural gas (LNG) facility on Lelu Island - Appendix J Technical Assessment Report - Freshwater Acidification and Eutrophication. [PNW LNG] Pacific NorthWest LNG Limited Partnership. Available from http://a100.gov.bc.ca/appsdata/epic/documents/p396/d37423/1395766902924_4c3e62c6c9b21ab36431891ca349aaa232612bd636fdc3a890dfb7d030c90064.pdf [accessed 30 April 2014].

Bunting, L., Leavitt, P.R., Weidman, P., and Vinebrooke, R.D. 2010. Regulation of the nitrogen biogeochemistry of mountain lakes by subsidies of terrestrial dissolved organic matter and the implications for climate studies. Limnol. Oceanogr. **55**: 333–345.

Carou, S., Dennis, I., Aherne, J., Ouimet, R., Arp, P.A., Watmough, S.A., DeMerchant, I., Shaw, M., Vet, B., Bouchet, V., and Moran, B. 2008. A national picture of acid deposition critical loads for forest soils of Canada. Can. Counc. Minist. Environ. Available from http://www.ccme.ca/assets/pdf/national_picture_acid_deposition_pn1412.pdf [accessed 30 April 2014].

Christensen, M.R., Graham, M.D., Vinebrooke, R.D., Findlay, D.L., Paterson, M.J., and Turner, M.A. 2006. Multiple anthropogenic stressors cause ecological surprises in boreal lakes. Glob. Chang. Biol. **12**: 2316–2322. doi: 10.1111/j.1365-2486.2006.01257.x.

Donahue, W.F., Turner, M.A., Hesslein, R.H., Weidman, P.R., and Curtis, P.J. 2001. The potential for climate change to modify the rate of recovery of boreal lakes from acidification via DOC-mediated increases in pH. Government of Canada, The Climate Change Action Fund. Ottawa, Ontario.

Esplin, G. 2014. Review of Pacific NorthWest LNG NOx emissions. T. Buck Suzuki Environmental Foundation. Prince Rupert, British Columbia.

Fulton, R.J. 1995. Surficial Materials of Canada (Map 1880A). Geological Survey of Canada. Available from http://atlas.nrcan.gc.ca/data/english/maps/geology/surficial_materials_map.pdf [accessed 30 April 2014].

Government of British Columbia. 2014. LNG and Pipeline Projects in B.C. Government of British Columbia. Available from http://engage.gov.bc.ca/lnginbc/lng-projects/ [accessed 30 April 2014].

Hazewinkel, R.R.O., Wolfe, A.P., Pla, S., Curtis, C., and Hadley, K. 2008. Have atmospheric emissions from the Athabasca Oil Sands impacted lakes in northeastern Alberta, Canada? Can. J. Fish. Aquat. Sci. **65**: 1554–1567. doi: 10.1139/F08-074.

Henriksen, A. 1980. Acidification of freshwaters--A large-scale titration. *In* Ecological impact of acid precipitation. *Edited by* D. Drablos and A. Tollan. SNSF-Project #1432, Oslo, Norway. pp. 68–74.

Hobbs, W.O., Lalonde, S. V, Vinebrooke, R.D., Konhauser, K.O., Weidman, P., Graham, M.D., and Wolfe, A.P. 2010. Algal-silica cycling and pigment diagenesis in recent alpine lake sediments: mechanisms and paleoecological implications. J. Paleolimnol. **44**: 613–628. doi: 10.1007/s10933-010-9441-5.

Hutchison, W.W., Berg, H.C., and Okulitch, A. V. 1973. Skeena River, British Columbia - Alaska (Map 1385A). Geological Survey of Canada. Available from http://ftp2.cits.rncan.gc.ca/pub/geott/ess_pubs/109/109184/gscmap-a_1385a_e_1979_mn01.pdf [accessed 30 April 2014].

Kalff, J. 2002. Limnology: inland water ecosystems. Prentice Hall, Upper Saddle River, NJ.

Keller, W., Yan, N.D., Gunn, J.M., and Henneberry, J. 2007. Recovery of acidified lakes: Lessons from Sudbury, Ontario Canada. Water, Air, Soil Pollut. Focus **7**: 317–322.

Kelly, C.A., Rudd, J.W.M., Hesslein, R.H., Sschindler, D.W., Dillon, P.J., Driscoll, C.T., Gherini, S.A., and Hecky, R.E. 1987. Prediction of biological acid neutralization in acid-sensitive lakes. Biogeochemistry **3**: 129–140. doi: 10.1007/BF02185189.

Knox, G. 2013. Air Advisory: Air Quality Impacts of Liquefied Natural Gas operations Proposed for Kitimat BC. Skeena Wild Conservation Trust. Terrace, British Columbia. Available from skeenawild.org/images/.../skeenawild-airquality-report-nov2013.pdf? [accessed 30 April 2014].

Matuszek, J.E., and Beggs, G.L. 1988. Fish species richness in relation to lake area, pH, and other abiotic factors in Ontario lakes. Can. J. Fish. Aquat. Sci. **45**: 1931–1941.

Ormerod, S.J., Dobson, M., Hildrew, A.G., and Townsend, C.R. 2010. Multiple stressors in freshwater ecosystems. Freshw. Biol. **55**: 1–4.

Schindler, D.W. 1986. The significance of in-lake production of alkalinity. Water. Air. Soil Pollut. **30**: 931–944. doi: 10.1007/BF00303358.

Schindler, D.W., and Lee, P.G. 2010. Comprehensive conservation planning to protect biodiversity and ecosystem services in Canadian boreal regions under a warming climate and increasing exploitation. Biol. Conserv. **143**: 1571–1586.

Schindler, D.W., Mills, K.H., Malley, D.F., Findlay, D.L., Shearer, J.A., Davies, I.J., Turner, M.A., Linsey, G.A., and Cruikshank, D.R. 1985. Long-term ecosystem stress: The effects of years of experimental acidification on a small lake. Science (80-.). **228**: 1395–1401. doi: 10.1126/science.228.4706.1395.

Shortreed, K.S., Hume, J.M.B., and Malange, K. 2007. Preliminary categorization of the productivity of 37 coastal and Skeena River system lakes in British Columbia. Can. Tech. Rep. Fish. Aquat. Sci. **2718**: 1–91.

Shortreed, K.S., Morton, K.F., Malange, K., and Hume, J.M.B. 2001. Factors limiting juvenile sockeye production and enhancement potential for selected B.C. nursery lakes. Can. Sci. Advis. Secr. Res. Doc. **2001/098**: 1–69.

Swain, L.G. 1987. Second Report on Chemical Sensitivity of BC Lakes to Acidic Inputs. British Columbia Ministry of Environment Lands and Parks, Environment and Resource Division, Water Mangement Branch. Available from www.env.gov.bc.ca/wat/wq/reference/acidrain/acidrain.html [accessed 30 April 2014].

Weidman, P., Schindler, D.W., and Vinebrooke, R.D. 2011. Pelagic food web interactions among benthic invertebrates and trout in mountain lakes. Freshw. Biol. **56**: 1081–1094. doi: 10.1111/j.1365-2427.2010.02552.x.

Weidman, P.R., Cruikshank, D.R., and Ranson, C.R. 1998. Trace metal data in water from lakes and streams of the Experimental Lakes Area, northwestern Ontario, 1987 to 1996. Can. Data Rep. Fish. Aquat. Sci. **1046**: 1–59.

Weidman, P.R., and Howell, T. 2005. Nearshore water quality of southeastern Lake Huron, 2003: Elevated nitrogen and fecal coliform bacteria (*Escherichia coli*). Etobicoke, Ontario.

Weidman, P.R., Vinebrooke, R.D., Thompson, P.L., and Schindler, D.W. 2014. Interactive effects of higher temperatures and dissolved organic carbon on planktonic communities in fishless mountain lakes. Freshw. Biol. **59**: 889–904.

Wright, R.F., and Schindler, D.W. 1995. Interactions of acid rain and global changes: Effects on terrestrial and aquatic ecosystems. Water. Air. Soil Pollut. **85**: 89–99.