Gramineae Seed Farm

Arthur & Laurel Hadland

[redacted]

August 5, 2017

Dear ~~Reader~~ Mr. Morton CEO

I applaud the decision to put Site C in front of the BC Utilities Commission (BCUC).

As the former Director for Area C of the Peace River Regional District (PRRD), we passed 2 motions to ask the BC Government to honour the Recommendations of the Environmental Review Panel to have this project reviewed by the BCUC. Both times, the requests were refused.

> **RECOMMENDATION 46:** If it is decided that the Project should proceed, a first step should be the referral of Project costs and hence unit energy costs and revenue requirements to the BC Utilities Commission for detailed examination.

The so-called Clean Energy Act (April 28, 2010) was designed to by-pass legislation and place Site C in a cattle chute designed for approval without an honest and transparent process.

The Sheppard co-gen plant adjacent to Calgary is equivalent to Site C and was constructed on budget ($1.3B). This option was eliminated by the *Clean Energy Act.*

The location of the proposed Site C reservoir within the sedimentary basin of the Peace River is a formula for a future catastrophic failure similar to the 1976 Teton Dam and the 2014 Mt. Polley dam failures.
Remember these dams were engineered by engineers.

Some of the factors affecting the geophysical instability of the proposed Site C reservoir.
The 4,010 slides identified in the 2006 LIDAR* confirms the SNC Lavalin (2009) statement:
"..the uncertainties in predicting both the extent and rate of the shoreline impacts lead to the proposal to adopt an observational approach for periodically reviewing and updating the reservoir impact lines after the reservoir has been filled."
http://www.bchydro.com/energy_in_bc/projects/site_c/document_centre/stage_2_reports.html
The professional and personal opinions in the various Attachments support the need for cancellation of this project.

Yours truly

Arthur A Hadland

ARTHUR HADLAND

[redacted]

OPEN LETTER April 3, 2015

BC HYDRO – OUR FAILED UTILITY

AND HERE ARE THE REASONS

This is an appeal to the BC business community and the ratepayers of our public utility BC Hydro and Power Authority [BCHPA] to investigate and better understand the negative impacts and onerous financial commitment of the unnecessary proposed Site C in the sedimentary basin of the Peace River. At the very least, this project must be reviewed by an independent BC Utilities Commission and at the most by a Royal Commission.

1. **Escalating Debt load** on the backs of BCHydro Power Authority rate payers. The total BCHPA debt in 2003 was $30 Billion, while in 2013 BCHydro CEO Charles Reid admitted an accumulated debt load of $70 Billion. (Ask for Newspaper details)
2. **Escalating cost of construction of proposed Site C.** Current cost estimate is $9 Billion. We know that the WAC Bennett Dam doubled in cost in a 6 year time frame. This means potentially another $16 Billion to $18 Billion added to the existing $70 Billion Debt. Note that there has been no business plan in place to retire this accumulating rate payer burden.
3. **There were 7 purposes** provided for the use for proposed Site C beginning with export to California to energizing 450,000 homes in BC, ending with export to California (On the last day of the Hearing). **This demonstrates no purpose for proposed Site C.**
4. **Provincial Credit Rating** is deteriorating and will likely be downgraded. Moody's letter indicates a total Citizen Debt Commitment estimated at $181 Billion. Compare our failed Provincial Resource Development Policies with Norway who is parallel in population, geography, and resources now has a wealth pool of $700+Billion, second only to Dubai! The question is: *Why can we not do as good as or better than Norway?*
5. **Much more affordable alternates**: The Shepherd co-generative gas plant on 60 acres in Calgary is equivalent to proposed Site C. It has been constructed on budget for $1.3 Billion and has a guaranteed 5 year rate of .08/Kw hour. This is a fraction of the cost of proposed Site C.
6. **Existing infrastructure**: The Burrard Thermal Plant at Port Moody is **paid for**, has been upgraded and is capable of energizing 700,000 homes at the flick of a switch and it is next to the main load.
7. **Safety Uncertainty** –"***The uncertainties in predicting both the extent and rate of the shoreline impacts lead to the proposal to adopt an observational approach for periodically reviewing and updating the reservoir impact lines after the reservoir has been filled.***" Statement in the September 2009 Klohn Crippen Berger and SNC Lavelin report produced for BC Hydro. This is supported by the report made by the Geological Survey Branch of British Columbia prepared for the Honorable Jack Weisgerber, Minister of Energy, Mines and Petroleum Resources in 1991. (Quaternary Geology and Landforms of Eastern Peace River Region, British Columbia, by N.R. Catto 1991) Other cautionary examples such as the Mount Polley Disaster, Teton Dam Failure and the Vajont Dam Collapse demonstrate that clay sedimentary basins are the absolute worst places to construct dam reservoirs.
8. **Cost escalations caused by missed expenses**: i.e. PST costs were missed by estimates, TOTAL costs rose from $ 7.9 Billion to $9 Billion in one month. Are there others??

9. **Most importantly, BCHPA DOES NOT have a social licence to interact with the Peace Region.** This glaring corporate deficiency continues after 57 years of impact on the Valley growth and two major hydro-electric dams. For example the District of Hudson's Hope has a decreasing population. [1400 in 1978, 970 in 2014] The community revenues should be $25 Million for industrial taxes, instead an arbitrary $1.2 M goes to the community coffers.
   This list goes on: the loss of First Nations (FN) historical sites, the Rocky Mountain Fort (1794) and Rocky Mountain Portage Fort (1806).
10. **Where is the $400 Million Peace Basin Trust Fund?** There is an existing Columbia Basin Trust recognizing past impacts. Why not one for the Peace?
11. **Former BCHPA CEO Reid, at a Chamber of Commerce meeting in June 2013, stated that the $1/2 Billion 'dividend' BCHPA pays to the Provincial Budget is borrowed money!!!**
    Does this mean our public utility is Bankrupt???

As a business community who understands that the bottom line is essential to running a successful business, how would you rate your public utility with the financial facts authored in this letter?

We as householders and ratepayers DEMAND a sober second review of the unnecessary proposed Site C Dam.

The retirement of the existing $70 Billion debt load is not addressed. The huge debt burden will be on the backs of all British Columbians **forever**.
DEBT IS NOT O.K.

Is there a Why????

The litany of poor economic performance can lead one to speculate there must be a hidden agenda for forcing proposed C on the backs of British Columbians!!!

Could it be a future sale of our Public Utility's assets to General Electric, as was proposed in 2005 but was rejected due to immediate public back-lash?

Or is it simply a make work project for SNC Lavalin on the backs of British Columbians?

To quote Harry Swain, Chairman of the Joint Review Panel: the province's failure to investigate alternatives to the dam was a "**dereliction of duty**."

Submitted by Arthur A Hadland, P.Ag, AACI(retired)
Citizen of the Peace,
Past Peace River Regional District Area C Director
Agrologist of the Year 2001
Food producer and Land Use Consultant

Background information available upon request.

Gramineae Seed Farm

Arthur & Laurel Hadland

[redacted]

July 16, 2016

Honourable Mike Morris
Solicitor General & Minister of Public Safety
Parliament Buildings,
Victoria BC
V8V 1X4

Honorable Ralph Goodale
Minister of Public Safety
House of Commons
Ottawa, Ontario
K1A 0A6

RE: Site C – A Public Safety Hazard

Dear Sirs:

In Sept. 2009, p. 9 Klohn Crippen Berger Ltd. and SNC-Lavalin Inc. Peace River – Site C Hydro Project Reservoir Shoreline Impacts Methodology and Criteria Report No. P05032A02-10-001 *[1]
made the following statement:
"The uncertainties in predicting both the extent and rate of the reservoir shoreline impacts lead to the proposal to adopt an observational approach for periodically reviewing and updating the reservoir impact lines after the reservoir has been filled."

This factor should have stopped the project instantly.

Instead the decision has been made to build a dam in sedimentary shales surrounded by slippery clays. Most of us lay people know that the shales were mud some 70 million years ago. When you add water and exposure of the shale to air, this supposed bedrock returns to mud. On top of it all, the reservoir would be surrounded by Montmorillonite clay soils which will slide when wet.

Are we really going to build a dam on mud?? Just goggle Teton Dam. The Teton Dam was also constructed in a sedimentary basin. The Teton Dam disaster of 1976 and the 2014 Mt. Polley Dam disaster tell it all.

In a recent report by BC Hydro to BCUC 'unexpected' geotechnical problems are acknowledged by the proponent. These include unexpected slope failure on the projects north bank, larger than expected deterioration of shale bedrock exposed during construction and a phenomenon called rock exposed swell.

Local citizens know that the failure of the Peace River Bridge in October 1957 was caused by the failure of the shale bedrock base on the north side of the Peace River.

These factors and the professional opinions employed by BC Hydro need to be examined in detail regarding the safety of human activities surrounding and within the proposed reservoir. There has been no outside examination of these factors. It has not been addressed as of the writing of this commentary.

This outstanding safety concern is further reinforced by the report commissioned by the Honorable Jack Weisgerber, Minister of Energy, Mines and Petroleum Resources in 1991. This report was prepared by the Geological Survey Branch of British Columbia (Quaternary Geology and Landforms of Eastern Peace River Region, British Columbia, *[2] by N.R. Catto 1991). This report was made without reference to the proposed flooding of the Lower Peace River Valley; rather it was commissioned to examine aggregate exploitation within the lower Peace River region. This report is brought to the attention of the reader regarding reservoir safety concerns.

.....2

These six cautionary quotes were made researching the potential for exploration or exploitation of aggregate sites in the eastern Peace River area:

1. "Mass movements, including rotational and translation glacial slides and a variety of sediment gravity flows, commonly occur along all the major streams."…..Page 2
2. "The high concentrations of montmorillonite and bentonite in the strata, however, together with their poorly consolidated nature, greatly increases susceptibility of these rocks to slope failure following fluvial (or arthropogenic) undercutting or overloading."…..Page 2
3. "The clays are generally plastic, susceptible to sediment gravity flow if disturbed, and contain a high proportion of material derived from the local Cretaceous bedrock."…..Page 5
4. "Mass movements in the region can be induced by the fluvial undercutting, natural overloading of the slopes (e.g. by debris flow from above), loss of internal cohesion due to sudden saturation (as was common during June, 1990), or by human activity. Evidence of past colluviation in the region is extensive (Bobrowsky et al. 1991), and extreme caution is required in any effort to exploit or utilize river valley slopes."…..Page 10
5. "Thus, all of the major terrain slopes present in the eastern Peace River Region are subject to slope failure. Extreme caution should therefore be observed in any effort to exploit or utilize river valley slopes."…..Page 15
6. "Valley slopes throughout the region are subject to slope failure and colluviation, and the development of these sites should be minimized."…..Page 17 summary excerpt

This message is intended for the politicians and the taxpayers of BC. We are the 'owners' of BC Hydro although the Government claims that there is only one share holder.

The taxpayers are unintentionally paying for the largest environmental and economic catastrophe of BC's 21st Century.

The professional review of the failure of the Taylor Bridge *[3], the 2009 statement by SNC Lavelin, the Attachie Slide and the many points made in the 1991 Weisgerber Report *[2] are all damning.
Just ask the downstream residents of Old Fort and Taylor how they view their personal safety.

There is ample evidence that this dam poses a serious safety issue. It is incumbent on your respective jurisdictions to conduct an independent professional review to certify that this project would be safe.

Yours truly

Arthur A Hadland

*[1] Klohn Crippen Berger Ltd. and SNC-Lavalin Inc. Peace River – Site C Hydro Project Reservoir Shoreline Impacts Methodology and Criteria
*[2] Quaternary Geology and Landforms of Eastern Peace River Region, British Columbia
*[3] The 1957 Peace River Bridge Collapse, Taylor BC

"Potentially, a government is the most dangerous threat to man's rights: it holds a legal monopoly on the use of physical force against legally disarmed victims." ~Ayn Rand

Gramineae Seed Farm

Arthur & Laurel Hadland

[redacted]

November 16, 2016

Honourable Mike Morris
Solicitor General & Minister of Public Safety
Parliament Buildings,
Victoria BC

RE: Public Safety of Proposed Site C

Thank you for your referral and response letter from the Comptroller of Water Rights.
The response letter dated Sept 23, 2016 does not provide a statement that the dam structure and reservoir area impacts are safe for citizens of Old Fort, Taylor and Peace River, Alberta.
I ask that your office provide a professional opinion on the dam's safety from an objective source that is not affiliated with the Provincial Liberal Government or the Proponent, BC Hydro.
The 1991 Report commissioned by the Honorable Jack Weisgerber, Minister of Energy, Mines and Petroleum Resources was prepared by the Geological Survey Branch of British Columbia by N.R. Catto *[1], plus the Sept. 2009 Klohn Crippen Berger Ltd. and SNC-Lavalin Inc. Peace River – Site C Hydro Project Reservoir Shoreline Impacts Methodology and Criteria *[2] on the uncertainty of the shoreline AND the potential parallel to both the 1976 Teton Dam Failure and the 2014 Mount Polley dam failure are sufficient justification for sourcing an outside opinion on the public safety of this project. A sedimentary basin is an extremely hazardous and unstable location for a water reservoir. Suffice to say that shale is not bedrock. It's old mud. This fact cannot be minimized or marginalized.

In addition, I have attached images of a significant recent slide of the slippery clays that destroyed the access road to the river.+
There are also unconfirmed reports that an industrial hoe became stuck when cutting a foundation for the cement batch plant. How does a hoe dig in bedrock and then become stuck in the same bedrock? Notice the slump line in the shale on Image 3. (bedrock) Bedrock needs to be blasted, not dug by a hoe. There were no slides or slumps in the bedrock on the WAC Bennett or the Peace Canyon Dams.

Awaiting a positive response.

Arthur A. Hadland

*[1] Quaternary Geology and Landforms of Eastern Peace River Region, British Columbia, 1991`
*[2] Sept. 2009 Klohn Crippen Berger Ltd. and SNC-Lavalin Inc. Peace River – Site C Hydro Project Reservoir Shoreline Impacts Methodology and Criteria Report No. P05032A02-10-001

cc: Auditor General for BC
BC Green Party
Adrian Dix, BC NDP
Honourable Ralph Goodale, Federal Minister of Public Safety
Auditor General of Alberta

Province of British Columbia
Ministry of Energy, Mines and
Petroleum Resources
Hon. Jack Weisgerber, Minister

MINERAL RESOURCES DIVISION
Geological Survey Branch

QUATERNARY GEOLOGY AND LANDFORMS OF THE EASTERN PEACE RIVER REGION, BRITISH COLUMBIA NTS 94A/1, 2, 7, 8

By N.R. Catto

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VICTORIA
BRITISH COLUMBIA
CANADA

MAY 1991

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INTRODUCTION

A multi-faceted series of investigations of the Quaternary geology of the Peace River region (Figure 1) of British Columbia were undertaken in 1990 (Bobrowsky *et al.*, 1991). As part of this program, the southeastern part of the region, which encompasses the 1:50 000 NTS map areas 94A/1 (Shearer Dale), 94A/2 (Fort St. John), 94A/7 (North Pine), and 94A/8 (Alces River), was mapped in detail (*see* Figures 2 to 5 in pocket). This work involved mapping from aerial photographs, followed by detailed stratigraphic and sedimentologic field investigations and laboratory analyses of sediment texture and mineralogical composition. The detailed surficial geology maps produced from this work are designed to be of practical use to industry, government, and the general public.

The extent of aggregate resources in the region, and the potential for recognition and exploitation of new resources, was not well known prior to detailed mapping, although deposits in the Fort St. John – Taylor area have been exploited for some years (Hora, 1988). Maynard (1988) commented upon the possibilities for utilizing peat resources for agricultural and other purposes, but comprehensive data were not available for the eastern Peace River region prior to the detailed mapping reported upon in this study.

This paper, therefore, is intended to accompany the maps (Figures 2 to 5 in pocket), and addresses three objectives:

- to discuss the composition, material properties, and genesis of the major types of

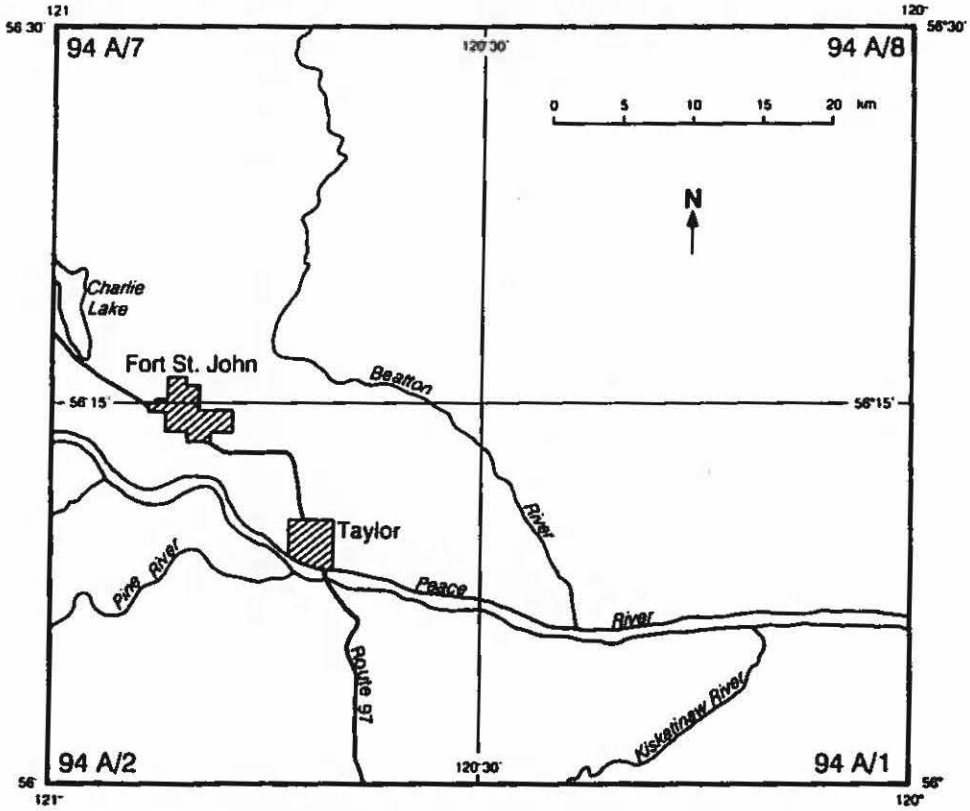

Figure 1. Location map of the Peace River area of British Columbia.

Quaternary geological units identified throughout the four map areas;

- to evaluate the aggregate and peat deposits and resources in the region; and
- to evaluate the environmental and engineering geological aspects of the region.

Study of the chronology of mass movement events and detailed stratigraphic analysis of the region formed other components of the research effort in the Peace River region, and are discussed elsewhere (Bobrowsky *et al.*, 1991).

REGIONAL SETTING

The Peace River region (Figure 1) lies along the western edge of the Alberta Plateau within the Interior Plains (Mathews, 1986). The present climate is continental boreal, marked by cold winters (January mean temperature –18°C), warm summers (July mean 17°C), moderate annual precipitation (600 mm, 200 mm of which falls as snow), a positive net moisture budget, and prevailing westerly winds (Environment Canada, 1984). Topographic effects along the deeply incised Peace River valley have created a 'thermal oasis', where temperatures regularly exceed those of the surrounding uplands and prairies by 5°C.

Vegetation in the region is dominated by the aspen (*Populus tremuloides)* parkland assemblage, with lesser amounts of alder (*Alnus rugosa*), birch (*Betula papyrifera)*, balsam poplar (*Populus balsamifera*), white and black spruce (*Picea glauca, P. mariana*), and scattered lodgepole pine (*Pinus contorta*) (Rowe, 1972). This assemblage was actively encroaching throughout the region prior to the advent of agricultural activity. Isolated patches of midgrass prairie, dominated by wheat grass (*Agropyron*), needle grass (*Stipa*), and sedges (*Carex*), are present in the eastern section of the region. Aspect, and the thermal oasis effect along the Peace River, have a major influence on microclimate and hence on the local vegetation cover. Along south-facing escarpments, warmth-loving plants such as prickly-pear (*Opuntia polycantha*) are infrequently present. The soils in the region are dominantly dark grey luvisols (under forested terrain) and black chernozems (under grasslands and long-cultivated areas).

The topography consists of a series of rolling plateaux and northeastward-sloping plains, locally interspersed with sharp cuesta slopes. Relief is approximately 300 metres. The region is dissected by an integrated dendritic drainage system tributary to the Peace River, which declines regularly in elevation from approximately 420 metres at the western margin of the mapped area to 400 metres at the provincial boundary. Valleys of the major tributary streams (Kiskatinaw, Beatton, Pine, Moberly, and Alces Rivers) are deeply incised, with local relief exceeding 150 metres. In general, the upland terrain south of the Peace River is more dissected and shows greater relief than that north of the river. Mass movements, including rotational and translational slides and a variety of sediment gravity flows, commonly occur along all the major streams.

The bedrock consists of the Upper Cretaceous Shaftesbury Formation (dark grey shales and siltstones, and argillaceous sandstones), the Dunvegan Formation (light grey sandstone and interbedded shale, with rare thin coal seams), and the Kaskapau Formation (silty shales with thin sandstone beds) (Stott, 1975). These strata represent a broad marine transgression–regression–transgression cycle, with several fluctuations of sea level recorded in the Dunvegan rocks. These units are generally undeformed in the eastern part of the Peace River region and dip at very low angles towards the southwest. In the southwesternmost part of the area, the bedrock has been affected by northeasterly-directed thrusting from the Rocky Mountains, and eastward-dipping strata are common although the bedrock structure has little influence on the topography or geomorphic development of the region. The high concentrations of montmorillonite and bentonite in the strata, however, together with their poorly consolidated nature, greatly increase the susceptibility of these rocks to slope failure following fluvial (or anthropogenic) undercutting or overloading. The friability of the strata

resulted in the erosion, transportation and incorporation of large quantities of the material into Quaternary deposits.

The Quaternary stratigraphic framework of the Peace River region has been extensively discussed by Bobrowsky (1989) and Bobrowsky *et al.* (1991). Further results with stratigraphic details, generated in part from the 1990 field and laboratory investigations, will be presented elsewhere (Bobrowsky *et al.,* in preparation), and consequently are not discussed in this contribution.

GEOLOGY

QUATERNARY GEOLOGY DESCRIPTION AND ANALYSIS

The terminology and symbols used to designate map units was developed by the British Columbia Ministries of Environment and Crown Lands (Howes and Kenk, 1988; *see* legend of Figures 2 to 5). Map units are classified in terms of texture, dominant genetic process, surface expression, geological (modifying) processes and, in some instances by specifying a qualifying descriptor. In locations where two or more sediment types are exposed within the boundaries of a single map unit, a composite unit symbol is used, with the dominant unit listed first. In areas where a unit is stratigraphically beneath a veneer or blanket of another, but influences the topographic expression or tonal qualities visible on aerial photographs, a compound symbol is used with the underlying unit symbol in the denominator.

Throughout the eastern Peace River region, many examples of complex sedimentary successions were observed, especially along the deeply incised river valleys or in areas where mass movement activity and alluvial reworking was prevalent. In these areas, the symbols are unavoidably complex, and the areas represented by each map unit relatively small. Such areas are subject to modification by further mass movement disturbances, and many such disturbances were observed during field research which post-dated the most recent aerial photographic coverage available. Users of these maps should be aware that subsequent mass movement activity in these areas may result in changes in terrain classification. In general, it is advisable to treat all slopes along the major rivers in the region as potentially unstable, and to plan accordingly.

The number of map units represented by distinct terrain classification symbols precludes discussion of each individual unit. The discussion which follows is therefore based upon the dominant genetic processes which each unit type represents. The unit types are discussed in order of diminishing prominence and areal extent.

GLACIOLACUSTRINE UNITS ($L^{G)}$

Sediments associated with map units interpreted as glaciolacustrine were deposited in one or more glacial lakes which were impounded to the east by the retreating Laurentide glaciers (Mathews, 1980; Bobrowsky *et al.*, 1991). The ice front prevented drainage via the present route to the east and northeast. These deposits are confined to elevations below 820 metres in the southern part of the region (Shearer Dale and southern Fort St. John map areas). In the map areas north of the Peace River (North Pine and Alces River), glaciolacustrine deposits are generally not found above 740 metres elevation.

The most common type of glaciolacustrine unit is composed dominantly of silty clay or clayey silt, commonly containing 5 to 15 per cent sand and scattered pebbles and larger clasts. The clays are generally plastic, susceptible to sediment gravity flow if disturbed, and contain a high proportion of material derived from the local Cretaceous bedrock. The sand fraction is composed dominantly of quartz, feldspar, chert, and carbonate minerals, and also contains trace quantities of garnet, hornblende, pyroxene, fluorite, tourmaline, titanite, and other heavy minerals derived in part from the Canadian Shield of northeastern Alberta and the Mackenzie District of the N.W.T. Orthoquartzite, sandstone, shale, granitic, and gneissic pebbles, along with clasts of other lithologies, were observed.

A variety of sedimentary structures are present in the finely textured glaciolacustrine sediments. Most exposures are stratified, with either fine stratification defined by alternating clay-rich and clay-poor layers, millimetres or tens of millimetres thick, with poorly-defined contacts; or with well-defined laminations and centimetre-thick beds of clay, silt, and sand. Rarely, glaciolacustrine silt and sandy-silt beds are cross-stratified, with the orientations of the strata indicating eastward flow. The sediments in many exposures have been disturbed by either syndepositional or post depositional mass movements, as indicated by contorted stratification. Other exposures have been altered by pedogenesis, and by frost action generated under the modern climate. Such disturbances are very common in the thinner stratigraphic sequences.

The fine glaciolacustrine sediments generally form a veneer (map symbol v; < 1 metre thick) or a blanket (b; > 1 metre thick) overlying other sediments. These units have no geomorphic form independent of the underlying unit. In most instances, the underlying material is undulating, rolling, or hummocky morainic diamicton. Contacts between these materials are commonly gradational and, thin, discontinuous beds and lenses of diamicton are frequently present in the basal 1 metre of the thicker glaciolacustrine assemblages.

Glaciolacustrine deposits more than 3 metres thick tend to form hummocky (h), rolling (m), or gently undulating (u) expanses with low relief, often dotted with small hollows where uncultivated. The composition and internal structure of these units is similar to that of the glaciolacustrine blankets and veneers. Much of this sediment type is under cultivation in the Peace River region, as it forms the most fertile and potentially productive material for pedogenesis and plant growth.

The glaciolacustrine silts and clays were deposited by sediment gravity underflows and suspension settling. Minor amounts of material (including most of the coarse clasts) were deposited by melting icebergs from the adjacent Laurentide glaciers. The genesis of these deposits is discussed extensively by Bobrowsky *et al.* (1991) and by Liverman (1989 and in preparation).

Minor amounts of glaciolacustrine sands and sandy silts are also present in the region. The units generally form thin blankets over morainic silty and clayey diamictons, often on eastward-facing slopes, and are laterally and vertically gradational into both diamictons and finer-textured glaciolacustrine sediments. The units generally are poorly or moderately sorted, and are not suitable for aggregate exploitation except for very local and small-scale use.

The deposits were formed by washing and reworking of previously deposited sediments during drainage of the glacial lake, as the ice front receded to the northeast. Drainage was relatively rapid, and hence the deposits are not areally extensive or well-developed. In addition, the dominantly east-west orientation of the basin, parallel to the prevailing winds, limited wave activity on the surfaces of the glacial lakes and hence precluded the formation of well-defined strandlines.

Other minor washed zones, too thin and laterally discontinuous to be mapped as separate units, are present on the surfaces of the fine-grained glaciolacustrine units. In many instances, washing of the surface of the deposits has continued to the present. Pedogenesis and cultivation have probably resulted in the destruction of other thin examples of these features.

Morainic Units (M)

In this study, sediments mapped and interpreted as morainic are diamictons, containing significant quantities of clay, silt, sand, and larger clasts. All of these units were either:

- deposited directly from glacial ice (true morainic units or tills), or
- were initially deposited from glacial ice but were subsequently substantially modified by sediment gravity flow or other mass movement processes prior to the deposition of any overlying glaciolacustrine or

glaciofluvial sediment, (for example, in subglacial cavities), or

- were initially deposited from glacial ice but were subsequently substantially modified by sediment gravity flow or other mass movement processes in a glaciolacustrine environment prior to the deposition of finer-textured glaciolacustrine sediments.

These qualifications allow the morainic units to be treated in terms of their geomorphic expression, texture, and mineralogical composition, without requiring differentiation of the precise mode of genesis. Depositional analysis of the diamicton sediments in the Peace River region, in common with most areas of British Columbia and western Canada, is a complex process requiring intensive examination of individual outcrops (often with inconclusive results). Such intensive sedimentological analyses are discussed elsewhere (Bobrowsky *et al.*, 1991; Bobrowsky *et al.*, in preparation; Liverman, 1989).

Diamicton units which have undergone any substantial modification after deposition from glacial ice cannot be classified as tills, and are technically not morainic deposits. The diamicton units in the eastern Peace River region have broadly similar physical properties, however, regardless of the exact mode of deposition of each unit. For practicality and ease of general discussion, therefore, all of the diamicton units were mapped as morainic units, and will be treated collectively in this paper. A more precise analysis of the diamictons present at any particular site should be undertaken prior to construction.

Texturally, the diamictons vary in matrix composition from silty clay to silty sand. Clay content ranges from 5 to 35 per cent, and sand content varies between 15 to 55 per cent. The proportion of large clasts is also variable, reaching a maximum of 25 per cent. Units with coarse clast contents of less than 5 per cent were mapped as glaciolacustrine sediments, with the rare coarse clasts interpreted as ice-rafted pebbles and cobbles. Generally, the diamictons are dominated by fine-grained matrices.

The diamictons contain a varied suite of minerals, including quartz, chert, feldspar, calcite, dolomite, biotite, vermiculite, magnetite, hornblende, garnet, pyroxene, tourmaline, corundum, apatite, titanite, and kyanite. The pebbles and cobbles are dominantly locally derived shale (from the Shaftesbury and Kaskapau Formations) and sandstone (from the Dunvegan Formation), with associated orthoquartzite, chert, limestone (rarely containing fragments of Devonian corals), granites (derived from both the Canadian Shield and the Omineca Range), gneiss, gabbro, and diabase. These mineralogical and petrological assemblages indicate that Cordilleran, Montane, and Laurentide source areas all contributed to the diamicton sediments. The presence of Laurentide granites and gneisses, and of fossilferous limestone clasts derived from the Devonian strata of northeastern Alberta, indicate that the diamicton units were deposited at some time after the initial Laurentide advance. These clasts in themselves, however, are not sufficient evidence to establish that the diamictons were deposited by Laurentide glaciers, as they could have been transported by ice-rafting in proglacial lakes and redeposited in nonglacigenic diamictons, such as subaqueous debris flows. Such units are commonly found associated with proglacial lacustrine sequences.

The internal structures within the morainic units show a wide range of styles. Most of the units are texturally homogeneous, without distinctive lenses or stratification. Some diamicton exposures, however, contain small sand lenses, generally aligned horizontally or subhorizontally. Although some of these lenses contain cross-stratification, lag and shadow structures, and graded bedding, the majority are internally structureless. Thin (1 to 2 cm) planar silt lenses, dipping easterly or northeasterly at low angles, are rarely present.

At several exposures, the alignment of the large pebbles and cobbles was measured, in order to ascertain the direction of sediment transport and to assist in interpretation of the genesis of the diamictons. Results from these

clast fabric analyses were extremely variable for the region's diamictons, with vector orientation strengths varying from almost perfectly random (principal eigenvalue = 0.36) to well-oriented (principal eigenvalue = 0.88). These variations indicate that the sediments mapped here as 'morainic' represent many styles and processes of deposition (Bobrowsky *et al.*, 1991).

The morainic units generally have rolling (m) or undulating (u) surfaces. Aprons are present surrounding bedrock-cored highs, and some bedrock highs are blanketed with morainic diamictons. Slopes vary from gentle (j) to moderately steep (k). Rare examples of oriented ridges (r) indicating ice flow are present in the eastern part of the region, and suggest Laurentide ice flow from the east-northeast and northeast.

The morainic deposits interpreted as true tills found in the Alces River, Shearer Dale, North Pine, and the eastern part of the St. John map areas were deposited by Laurentide ice, moving from the east-northeast and northeast. These units which can be confidently identified as undisturbed tills, however, form a small proportion of the total 'morainic' assemblage. Most of the diamictons have undergone some modification, most commonly by sediment gravity flow. The diamicton units in the southwestern part of the Fort St. John map area contain very few granitic and gneissic clasts derived from the Canadian Shield, and some are completely devoid of these clasts. These units are interpreted as the products of Montane and Cordilleran glaciation, generally reworked after initial sedimentation, with some Laurentide clasts added through ice-rafting in proglacial lacustrine environments. The sedimentology of these deposits, and the stratigraphic implications, are discussed further in Bobrowsky *et al.* (1991), Liverman (1989), and Bobrowsky *et al.* (in preparation).

Fluvial Units (F)

Fluvial units include sand and gravel bars adjacent to the major rivers, minor alluvial fans and small aprons developed at the bases of some escarpments, and valley fill deposits along the lesser tributaries. Much alluvial modification of colluviated deposits has occurred along the deeper parts of the major rivers in the region, resulting in the development of complexly interbedded and washed fluvial/colluvial assemblages.

Texturally, the fluvial deposits vary from silt and clay to grain-supported coarse gravel. Sand and fine gravel units are the most common types present. The deposits are generally moderately to well-sorted, except where modified by or interbedded with colluviated materials. Clast types present commonly include sandstone, shale, orthoquartzite, chert, carbonates, granites, granodiorites, and gneisses, derived from Laurentide, Cordilleran, and Montane sources. The deposits are generally thick along the major streams, but thin in minor tributary areas. All of the mappable fluvial units were formed post-glacially, as indicated by their stratigraphic position and by ^{14}C dating (Bobrowsky *et al.*, 1991).

The lateral extent, composition, and internal structure of the fluvial units is directly related to the stream type. The largest streams in the region, the Peace and Pine Rivers, display both sandy braided and wandering reaches. Sedimentation along these streams is characterised by the development of large sand and gravel flats and longitudinal and lateral bars. The internal structures of these geomorphic features are marked by fining-upward sequences of well-sorted trough cross-stratified gravel and sand, with associated planar tabular and asymptotic cross-bedding. Imbricated gravel sheets are commonly developed on the upstream sides of the bars. The large bars and flats are commonly capped with medium and fine-grained sand and silt veneers, often rippled or horizontally laminated, that represent a combination of low-energy fluvial sedimentation during receding floods and aeolian reworking over the exposed surfaces.

Evidence preserved in the sedimentary record indicates that fluctuations of water levels

in the Peace River were much greater in previous times than on today's regulated stream. Evidence of similar fluctuations is present in the sediments found along the Pine River.

Trunk channel (thalweg) deposits, consisting of well-sorted sands and gravels, are commonly interbedded in the bar and flat sequences, indicating irregular channel switching and avulsion. The main channel of the Peace River has migrated as much as 4 kilometres south of its present position along the reach southwest of Fort St. John (Seyers and Buchanan, 1990).

Pre-existing river channel positions are also indicated by the larger gravel and sand deposits in the Taylor area, many of which have been or are being actively exploited as aggregate sources. These sequences represent lateral and longitudinal bars formed in the earliest post-glacial stage of the Peace River. A ^{14}C date obtained from a *Bison sp.* bone dates this event at 10 240±160 years B.P. (AECV – 1206C). This date has necessitated revision of the originally assigned mid-Wisconsinan age for some of the gravels in the Taylor area (Mathews, 1978). The geomorphic evidence, coupled with ongoing stratigraphic and chronologic investigations, indicates that all of the gravels in the Taylor area are post-glacial deposits (Bobrowsky *et al.*, 1991; Bobrowsky *et al.*, in preparation).

The other major streams in the region, the Kiskatinaw, Moberly, Beatton, and Alces Rivers, are all meandering systems which have become ingrown as a result of downcutting induced by falls in level of the Peace River. This downcutting has recently accelerated due to the regulation of the Peace, and will probably become more pronounced in the Beatton, Alces, and Kiskatinaw valleys if the Peace River is further dammed at Site C. Sediments are deposited along these streams as point bars, consisting of cross-strata successively fining upwards from coarse to medium sand, to fine sand and silt, and finally to silt and clay. The gently dipping cross-beds were deposited during successive falling water stages associated with seasonal flooding. The absence of coarser gravel deposits, or other sediments associated with thalweg channels, indicates that erosion has progressed predominantly by downcutting.

COLLUVIAL UNITS (C)

Units mapped as colluvial are predominantly diamictons, or poorly-sorted sandy and clayey silts. Surface washing, and to a lesser extent sorting during colluviation, has resulted in a concentration of coarser clasts on the surfaces of many colluvial units. The colluvial units are thus generally coarser than the morainic diamictons. The colluvial sediment is derived from a number of sources, but most deposits incorporate morainic, glaciolacustrine, and bedrock material. Many are interbedded with alluvial deposits, and have undergone surface washing. The geomorphic expression of these units is somewhat variable, but most are roughly undulating or hummocky, with steep or moderately steep slopes. Isolated depressions, ridges, and upthrown blocks of sediment are common.

Colluviation in the Peace River region occurs in several dynamic styles. Rotational slides (slumps) are commonly the first stage in an actively failing area. Failure involves motion of a cohesive block of material as a unit, without internal deformation. In the Peace River region, these blocks may be several tens of metres thick and several hundreds of square metres in area. Although failure surfaces can occur in glaciolacustrine strata, the failure plane is most commonly situated within the bedrock. This is especially true where shale units are involved.

Slumping is generally followed by internal deformation of the weakened material, generation of flows from the toe of the slump block, and flow of material in the exposed headwall of the block. These debris flows are generally laterally extensive, and result in considerable modification of the original slump block topography, usually to the point of completely obscuring the original morphology. Along river valleys where material is constantly removed from the toes by fluvial erosion, flow from the

toe continues essentially constantly (although the rates vary widely throughout a year and between years), and thus slope failure by debris flow results in essentially continuous modification of the terrain. This situation exists along all of the major tributaries to the Peace River (especially along the Beatton and Kiskatinaw Rivers), and debris flow colluvial deposits thus form a large proportion of the margins of these streams. Along the Peace River, removal of material from the toes is often not as rapid, because many of the deposits terminate at abandoned or seldom-occupied channels along the margins of the braided and wandering stream reaches. In these areas, preservation of the original slump morphology is more likely, although modification from debris flows induced from above the slump blocks is very extensive.

Mass movements in the region can be induced by fluvial undercutting, natural overloading of the slopes (*eg.* by debris flow from above), loss of internal cohesion due to sudden saturation (as was common during June 1990), or by human activity. Evidence of past colluviation in the region is extensive (Bobrowsky *et al.*, 1991), and extreme caution is required in any effort to exploit or utilize river valley slopes.

Organic Units (O)

Organic units are defined as those composed largely of organic materials resulting from the accumulation of plant material, containing at least 30 per cent organic material by weight (Howes and Kenk, 1988). They are associated with fens and bogs developed above relatively impermeable glaciolacustrine, lacustrine, and morainic materials. The surfaces of the units are generally level, forming veneers (v), blankets (b), and plains (p).

The organic deposits are classified according to the system of the Canadian Soil Survey Committee (1978). Fibric (f) deposits are the most common surface forms. Many of these deposits are associated with standing or seasonal water in sedge (*Carex*) fenlands, and are composed dominantly of *Carex* fragments. Decomposition of these deposits has not progressed to a large degree (1 to 4 on the Von Post scale, as used by the Canadian Soil Survey Committee), and many of the fibric layers are essentially unaltered plant debris. Local detrital transport of plant debris and small amounts of clay and silt has affected some fenlands, especially those adjacent to standing bodies of water or streams.

Mesic (u) deposits are rarely encountered as surface features, but underlie approximately 10 per cent of the fibric units. These units display an intermediate degree of decomposition (5 to 6 on the Von Post scale). Mesic horizons which underlie fibric *Carex* horizons are composed of decomposed *Carex* fragments. In contrast, some surficial mesic units are dominated by remains of *Sphagnum* moss, such as the unit exposed in the northeastern part of the North Pine map area at UTM 508619. This exposure represents the thickest mesic deposit observed in the region, with a total depth of 120 centimetres of *Sphagnum* peat, and has a surface area of approximately 0.07 square kilometre.

Humic units (those with Von Post decomposition values of 7 or greater) are not exposed on the surface within the region. Thin humic horizons were rarely encountered at the bases of mesic *Sphagnum* successions, but many of these horizons also contained substantial quantities of silt and clay. The thickest humic horizon measured, at UTM 508619 in the North Pine map area, was 10 centimetres.

Glaciofluvial Units (FG)

Units mapped as glaciofluvial are associated with morainic or glaciolacustrine deposits, are isolated from the major river systems, and form undulating, elongate ridges. The major area of occurrence in the eastern Peace River region is a northwest trending belt of isolated, undulating mounds 15 to 30 metres high, located west and southwest of Fort St. John in the North Pine and Fort St. John map areas.

The glaciofluvial deposits are well-sorted sands and granule, pebble, and cobble gravels. Clast assemblages are dominated by feld-

spathic sandstone and orthoquartzite, with lesser amounts of limestone, granite (predominantly from Canadian Shield sources, although some clasts derived from the Omineca Range are also present), gneiss, and minor amounts of chert. The mineralogy of the units indicates that material from Laurentide, Cordilleran, and Montane sources has been incorporated in the deposits. These deposits are currently being exploited as sources of aggregate.

Sedimentary structures within the glaciofluvial units, and their relationship with the adjacent glacigenic sediments, suggest that the deposits formed predominantly as fans, fan-deltas, and aprons developed along the margins of retreating Laurentide ice, rather than as subglacial esker segments. Flow indicators, such as cross-stratification and clast imbrication, measured in active aggregate pits in the Grand Haven – Fort St. John area vary in direction but are dominantly indicative of southwestern and southeastern flow. These directions are normal and parallel to the postulated ice front in the area.

Lacustrine Units (L)

Units mapped as lacustrine were deposited in shallow lakes not developed as a result of glaciation. These sediments thus represent suspension settling and minor underflow deposits that were exposed when small lakes partially or totally dissipated. The lacustrine units are of very limited areal extent.

These units are composed of silt and silty clay, either horizontally laminated or structureless, and lack large clasts and associated diamicton beds. Their surface expression generally takes the form of a veneer or blanket over underlying glaciolacustrine silts and clays, or (for thicker deposits) as small, featureless plains. The sediments commonly border existing or ephemeral ponds and sloughs.

Eolian Units (E)

Eolian units are uncommon in the eastern Peace River region. Although thin veneers of eolian silt and silty sand loess rarely occur as caps over glaciolacustrine, morainic, and fluvial sediments, these deposits are too thin and limited in areal extent to be mappable. The loess veneers do not have a distinctive geomorphic expression.

Veneers of eolian sand are present in the northeastern part of the North Pine map area. These units consist of thin, structureless, medium to fine-grained, well to moderately-sorted sand, generally overlying undulating glaciolacustrine and/or morainic deposits. Small mounds, which represent incipient, poorly-developed, or highly modified dome dunes are present in some areas, but generally are too small to be confidently recognized on aerial photographs. The few cross-strata preserved on the flanks of these dome dunes suggest westerly wind activity, but the number and degree of preservation of cross-strata is not sufficient to permit regional conclusions to be formulated. The deposits are too thin and fine grained to be suitable as sand aggregate sources.

RESOURCES

AGGREGATE RESOURCES

Units currently exploited for sand and/or gravel include those mapped as fluvial (terrace deposits along the Peace River), and glaciofluvial (in the unit sporadically exposed in the Grand Haven – Fort St. John area). The lateral extents of both of these unit types are well known locally, and extraction of material from the deposits has been conducted for several years (Hora, 1988). Additional aggregate extraction operations could be developed in currently unexploited parts of these units.

Few potential new sources of aggregate are present in the region. No mappable deposits of unexploited gravel units were observed. The rare examples of sand-dominated glaciolacustrine sediments and eolian deposits are too thin, limited in areal extent, and in many instances too poorly sorted to be satisfactory as sources of sandy aggregate. The low concentration of pebbles and larger clasts in the morainic diamicton deposits limits their utility as aggregate sources. Extensive processing would be required to isolate the 5 to 25 per cent gravel fraction from the silt and clay matrix. Some diamicton deposits observed contained chert clasts, which could prove unsuitable in some aggregate applications.

Bedrock exposures are present along the major river valleys, although they are commonly obscured by colluvium. The majority of the bedrock in the region is unsuitable for aggregate production, however, as it is dominated by shaly strata (Shaftesbury and Kaskapau Formations). Sandy beds within the Dunvegan Formation could possibly be used as aggregate sources, but contain substantial amounts of silt and clay and are poorly consolidated. In addition, these beds contain chert and bentonite, both of which are unsuitable for aggregate.

Aggregate resources in the region, therefore, are somewhat limited. At present, local demand for aggregate is met by exploitation of the glaciofluvial and elevated fluvial deposits in the vicinity of Fort St. John and Taylor.

PEAT RESOURCES

In a preliminary assessment, Maynard (1988) rated the eastern Peace River region as having a relatively low potential as a peat resource area. This assessment has been largely confirmed by field study. The majority of the organic deposits in the region are fibric units dominated by *Carex* fragments, associated with fenlands. These units are unsuitable for use in agricultural applications.

Mesic *Sphagnum* peat deposits are present at scattered localities, most notably in the eastern part of the North Pine map area, but these deposits are small and thin. The estimated total volume of the largest deposit is approximately 60 000 cubic metres, which limits its use. Preliminary investigations suggest the the map areas north and northwest of the study region may contain larger, more economic peat deposits.

ENVIRONMENTAL AND ENGINEERING GEOLOGY

Planning for construction, hydroelectric development, and waste disposal in the eastern Peace River region will require a knowledge of the engineering geological properties and potential environmental geological hazards associated with the Quaternary deposits. Although the Quaternary stratigraphy throughout most of the region is relatively simple, complex sedimentological successions are present within stratigraphic and geomorphologic units at many localities. In addition, successions found in areas subject to colluviation are commonly stratigraphically and geomorphologically complex. The major environmental and engineering geological concerns in the region centre around slope stability and waste disposal.

SLOPE STABILITY

Slope failure is ubiquitous along all of the major streams in the region. The extent of colluvial deposits formed by rotational slides (slumps) and flows indicates that all of the river banks should be regarded as potentially unstable. Sedimentological and chronological investigations have indicated that mass movements have occurred regularly since deglaciation (Bobrowsky *et al.*, 1991). During the 1990 field season, many active examples of both styles of mass movements induced by fluvial undercutting, overloading of the slopes, and loss of internal cohesion due to sudden saturation were observed. Failures along the north side of the Peace River valley have necessitated the periodic repair and relocation of several parts of Highway 29, and other damage to roadways is evident along the Kiskatinaw, Beatton, and Pine Rivers, and along other tributary streams.

The units mapped as colluvium (C) should be regarded as potentially unstable, and subject to failure if disturbed by any form of construction. The morainic units (M), characterized by silty and clayey matrices and low concentrations of coarse clasts, are subject to failure in areas where they crop out along river valleys or at the crests of slopes. These diamictons do not differ greatly in stability from the glaciolacustrine silt and clay units (LG), and failures of both sediment types are common. Large-scale failures in fluvial deposits (F) are relatively rare, due to the coarse texture of most fluvial units. Small grain flow failures are common, however, where the sediment is subject to fluvial undercutting or where colluviation of adjacent units has left fluvial sediments without lateral support. Many slope failure planes are developed in the underlying shale bedrock, and thus any overlying surficial unit can undergo failure if the bedrock loses lateral support due to fluvial downcutting.

Thus, all of the major terrain units present in the eastern Peace River region are subject to slope failure. Extreme caution should therefore be observed in any effort to exploit or utilize river valley slopes.

WASTE DISPOSAL

In order for a sedimentary unit to be suitable for the disposal of liquid waste, it must be relatively impermeable and isolated from the regional groundwater system, as well as not subject to slope failure. In areas removed from the major river valleys, both glaciolacustrine silt and clay units and morainic diamicton units with fine-textured matrices are potentially suitable for waste disposal. Many of these deposits, however, contain sand lenses which are permeable. Thus, extensive site investigation must be undertaken prior to designation of any waste

SUMMARY

Sediments exposed in the eastern Peace River region consist dominantly of fine-grained glaciolacustrine deposits and morainic silty and clayey diamictons. Fluvial and colluvial deposits are present along the Peace River and its major tributaries. Organic deposits consist mainly of fibric units derived from *Carex*, with lesser amounts of mesic *Sphagnum* deposits. Glaciofluvial sands and gravels, lacustrine silts, and eolian sands are present in minor amounts in isolated areas.

Aggregate exploitation in the region is confined to the glaciofluvial deposits, and to terraces of coarse fluvial sediments along the Peace River. No new, readily accessible sources of aggregate were noted. Peat resources in the region are also limited, and economic exploitation is not feasible at present.

Valley slopes throughout the region are subject to slope failure and colluviation, and development of these sites should be minimized. Liquid and solid waste disposal sites should be located in thick fine-textured glaciolacustrine and morainic units, but only after sedimentological investigation.

ACKNOWLEDGMENTS

This research was supported by a British Columbia Geoscience Research Grant. I am indebted to Dr. P.T. Bobrowsky and V.M. Levson of the Surficial Geology Unit, British Columbia Ministry of Energy, Mines, and Petroleum Resources, for extensive discussions of Peace River geology. G. Bradbury provided capable assistance in the field.

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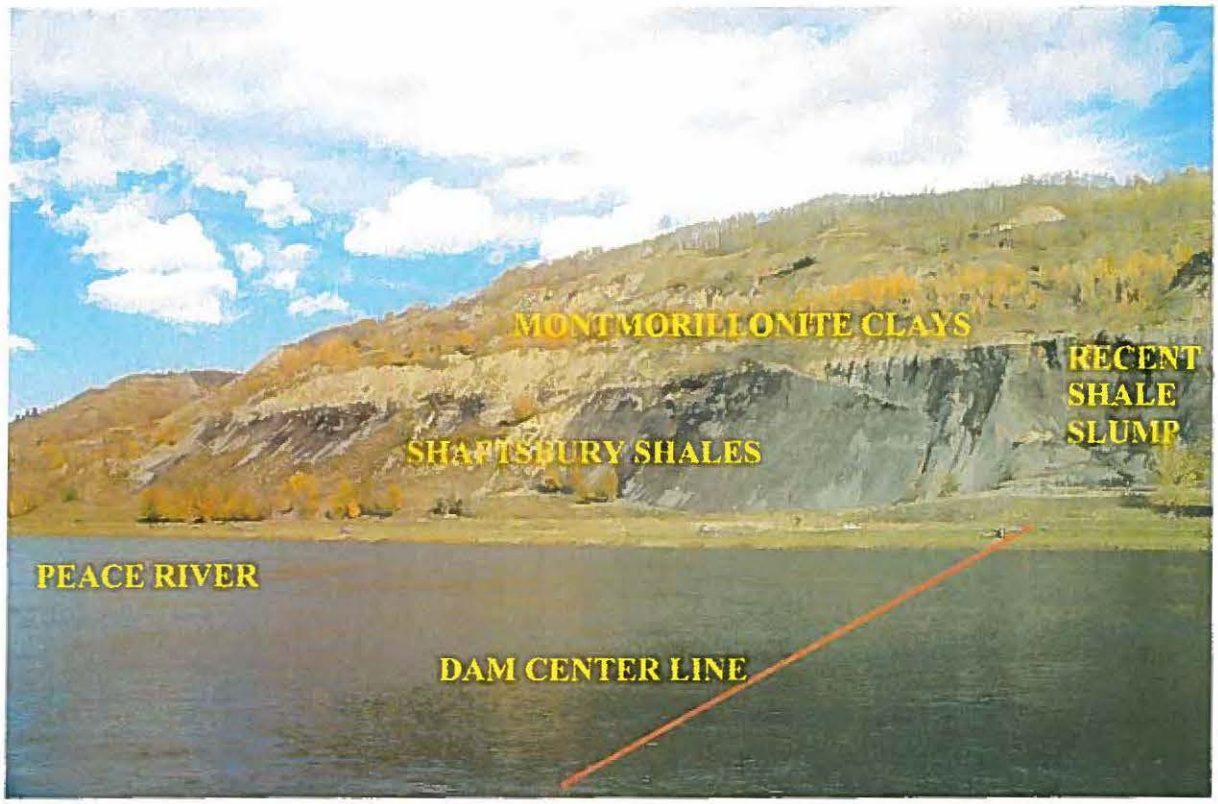
Opinion from the Peace (revised July 24, 2016)

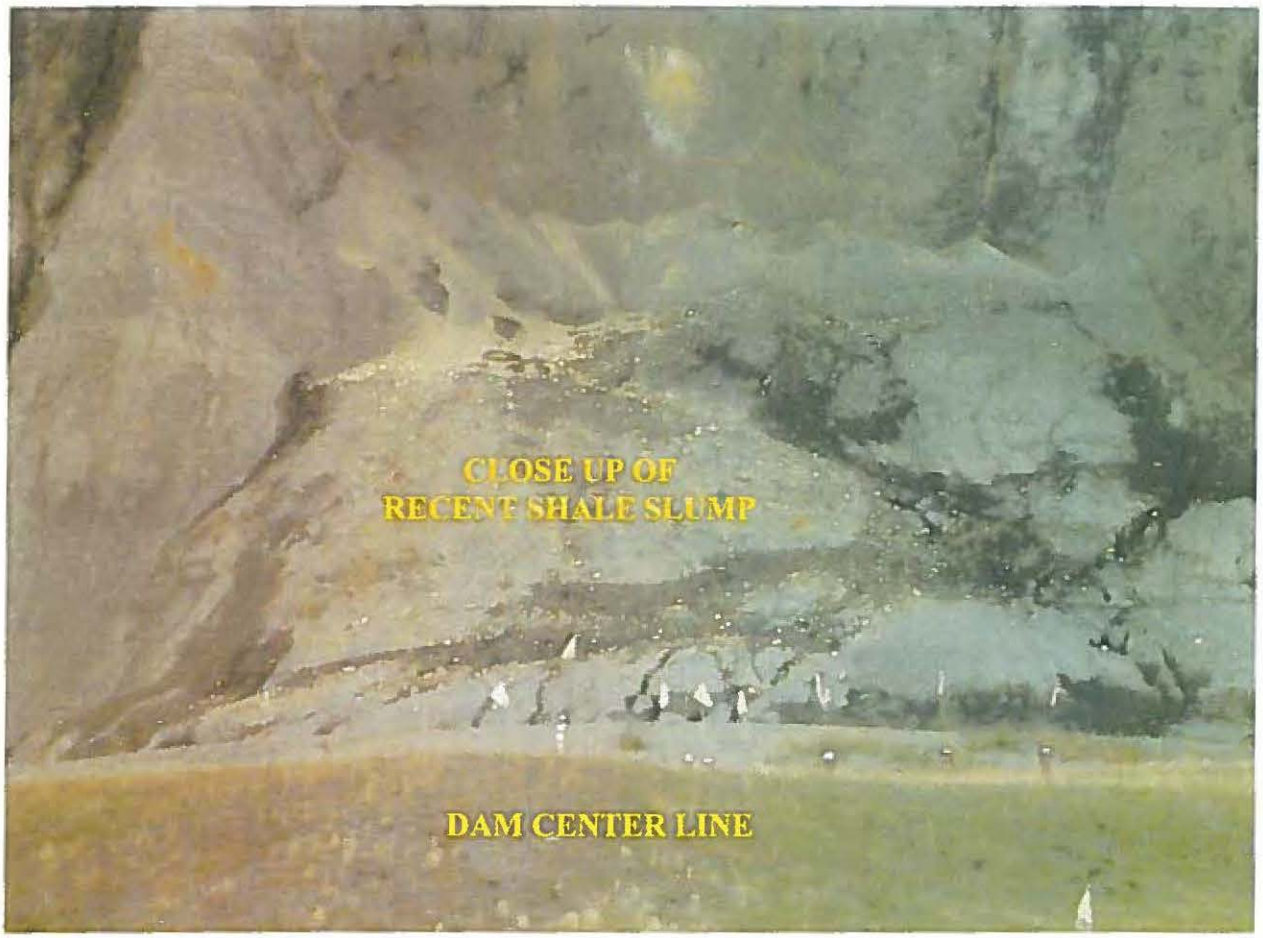
Proposed Site C would destroy a productive river valley equal to the distance from Vancouver to Chilliwack. Would you like this project in your back yard? Do you think this flooding could be considered green and clean!!!

The lack of transparency by the Provincial government regarding the proposed flooding of the Peace River will commit BC citizens to participating in British Columbia's Environmental Disaster of the 21st Century. In order to emphasize this statement please refer to the following information.

The reader should note that the first two dams on the Peace (WAC Bennett and Peace Canyon) are imbedded in igneous bedrock and not in sedimentary material such as exists at proposed Site C.



This photo shows an overview of the proposed Site C dam axis with the very unstable Montmorillonite clays perched on top of the Shaftesbury shales. As long as these shales and clays are dry they remain stable. However, there is no way of guaranteeing they will remain dry. Man does not have control over the periods of heavy rain that can occur.

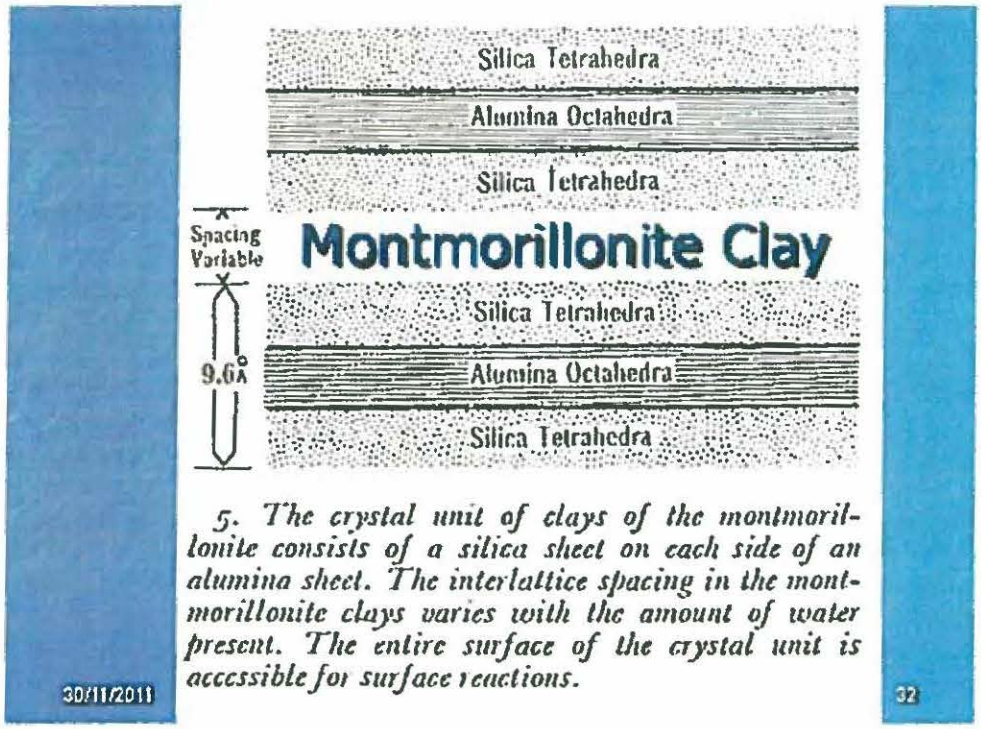


This 2011 photo shows the recent slide of the sedimentary rock (Shaftsbury shales) lying above the axis of the proposed Site C dam site. This shale slump (slide), directly on the centerline of the proposed Site C, occurred sometime during the last 24 months and has buried the exploratory adit (mine or tunnel) that was constructed by BC Hydro (BCHPA) in the late 1970s. This failure of the shale substrate parallels the causes of the Peace River Bridge failure in 1957. This Shale cannot be considered to be bedrock. The other numerous slope failures along the River Valley can likely be attributed to the wetting of the Montmorillonite clay soils overlying this shale base.

It is interesting to note that there is no known reference in any of the engineering reports referring to or acknowledging the presence of Montmorillonite clay soils and their unique characteristics. These characteristics contribute to the unstable shorelines and breaks all along the lower Peace River valley. Refer to the 1991 Weisgerber Report for confirmation of this statement.

A detailed explanation of Montmorillonite clay follows on the next page.

The structure of Montmorillonite clay (excerpted from US Department of Agriculture Yearbook 1957, pg. 34):



The wetting of these unconsolidated materials with water causes the thin plates to separate. When the platelets are on an inclined plane the coefficient of friction is reduced to the point where they will slide due to gravitational forces. The Attachie Slide in 1973, the BCR hill in the 1980s, and the Big Bam ski hill slide in 1996 are all examples of this phenomenon. Numerous other slides in earlier eras are located all along the undisturbed valley slopes. Any human disturbance in combination with high rainfall events exacerbates the slumping process along the edges of the Peace River Valley. There were extremely high rainfall years preceding the bridge collapse (1957), the Attachie slide (1973), and the ski hill failure (1996).

Aerial view of the Attachie Slide May 26, 1973 which dammed the Peace River for approximately 10 hours. This site is within the proposed Site C reservoir.

The proceeding discussion illustrates why the following comments were made by the BCHPA engineering contractor firm: Pg. 9 Klohn Crippen Berger and SNC-Lavalin September 2009 Report

http://www.bchydro.com/energy_in_bc/projects/site_c/document_centre/stage_2_reports.html
"..the uncertainties in predicting both the extent and rate of the shoreline impacts lead to the proposal to adopt an observational approach for periodically reviewing and updating the reservoir impact lines after the reservoir has been filled."

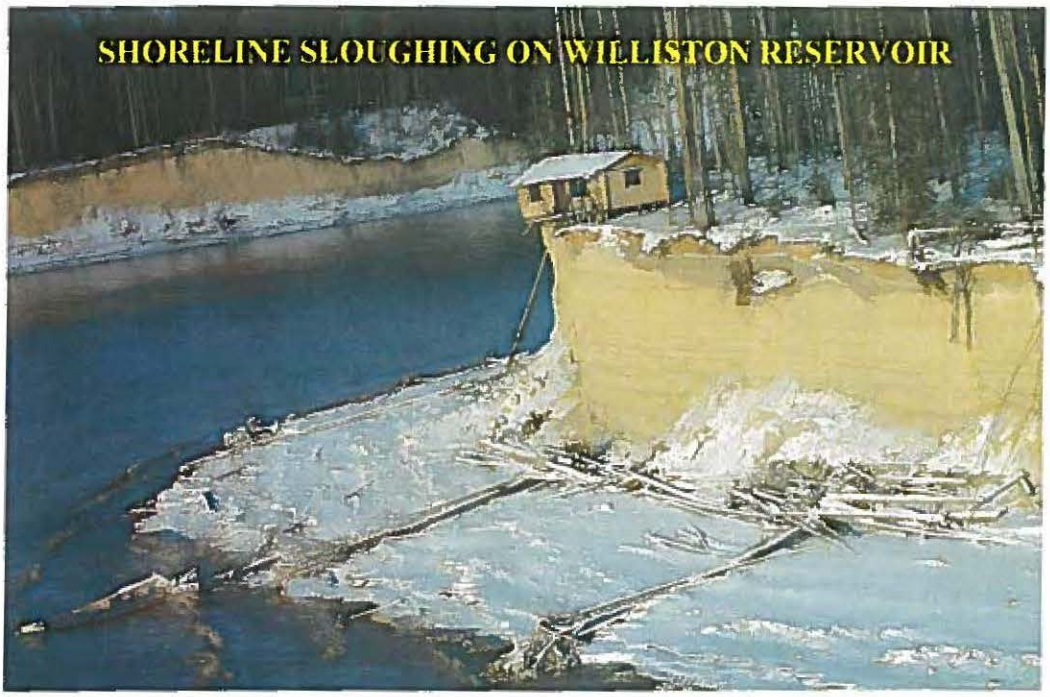
This proposal by a professional engineering firm should have had the proponents' (BC Gov't) hair standing on end and basically been a show stopper. Now it is doubtful that there will be any further objective analysis, as it appears that this firm has now taken an advocacy role. It is interesting to note that Gwyn Morgan, Chairman of SNC Lavalin was the energy advisor to the Premier of BC, Christy Clark.

From the Thurber 1976 report on proposed Site C:
"The preliminary "safeline" is a conservatively located line above which the security of minor physical facilities, particularly dwellings, can be assured. It is based only on probable effects of the reservoir upon slope stability with causes unrelated to reservoir action being excluded. The safeline is not to be confused with the probable limit of erosion or sloughing(sometimes called the "breakline"), which does not allow for any margin of safety, or with the "takeline" which is a line used to designate land to be purchased or restricted, as a result of development."

These lines have not been defined for the proposed Site C reservoir. **WHY NOT?**

BCHPA needs to be compelled to define these lines within the proposed reservoir prior to advancement of this project. If they are unable to undertake this task then it is suggested that this project cannot proceed any further as a fiduciary responsibility to the citizens of BC is implicit in this utility's (BCHPA) mandate.

It is also interesting to note that a small area near the WAC Bennett dam was mapped, defining a SAFELINE in the early 1970s. That line has since been exceeded in many places by the sloughing shoreline of that reservoir. The soils in this particular area are sandy and silty loam and have a different failure pattern as compared to the montmorillonite soils that are predominant in the proposed Site C reservoir. The following photo (from 2009) of a cabin lying on the expanding shoreline of the Williston Reservoir illustrates the inability of engineering technologies to accurately predict shoreline impacts along reservoir perimeters. Please note that the expansion of this shoreline perimeter still continues, some 42 years after the impoundment of the Williston Reservoir.



This site is approximately 8 miles west of the WAC Bennett dam. This cabin was built in 1976, at that time, the shoreline of the Williston reservoir was one third of a mile away from the cabin site. The cabin was built on the safe side of the defined safeline, 33 years prior to that picture being taken. This cabin was lost in 2009 the year the photo was taken.

These factors are all contributing to and reinforcing common sense observations that to proceed with further reservoir construction within the sedimentary basin of the lower Peace River is to create an environmental mess of unknown magnitude.

BC Hydro is on slippery ground in more ways than one. Citizens are encouraged to find out more about BC Hydro's $20 Billion debt, deferral payments on another $5B debt, plus the total debt commitment due to Independent Power Producers [confirmed to be $50+ Billion]. Citizens need to take back their ownership of their Public Utility. At the present time the total debt is $76 Billion. Ask yourself why the BC Utility Commission is not involved in this process.

The natural gas cogeneration of 7 Site C's can be built for the projected $9 Billion cost.
Site C is unnecessary, irresponsible and UNSAFE.
The existing and paid for Burrard Thermal Plant in Port Moody is capable of powering 700,000 homes. This is equivalent power as the proposed Site C.

Destroying a river valley is neither clean nor green.

Arthur A. Hadland

Arthur Hadland is a farmer, consulting Agrologist and Past PRRD Area C Director.

The Association of
PROFESSIONAL ENGINEERS AND GEOSCIENTISTS
of the Province of British Columbia
PEACE RIVER BRANCH

The 1957 Peace River Bridge Collapse, Taylor BC

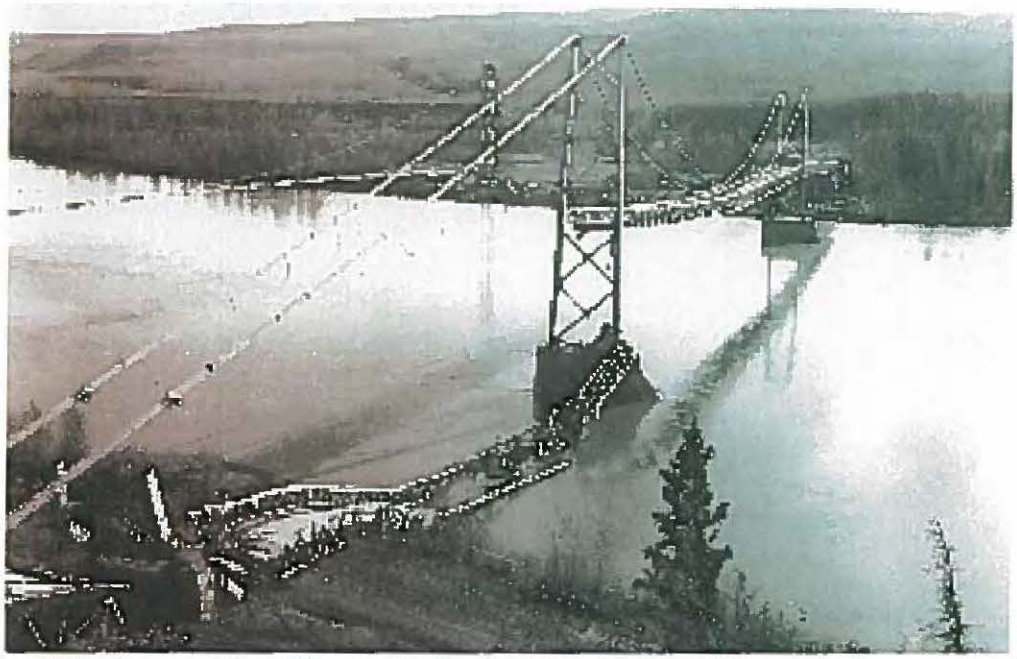
Did you know that one of Canada's most costly landslides occurred right here in the Peace River region? At a cost of 60 million dollars to dismantle and replace the collapsed Peace River bridge near Taylor, BC, the landslide that destroyed that bridge remains probably the costliest ever. This bridge collapse illustrates the important linkage between engineering and geosciences in the Peace River region.

The original bridge was built in 1942 by the US Public Roads Administration as part of the wartime construction of the Alaska Highway. At the time of its opening it was considered one of the great bridges in the Dominion of Canada. The bridge was a suspension type bridge. The length of the bridge was 647 m. At the time of the bridge collapse (October 16, 1957), the highway was part of the Northwest Highway System under the authority of the Government of Canada. The Princess Patricia's Canadian Light Infantry, based out of Whitehorse, Yukon, was responsible for the maintenance of the bridge and highway.

The suspension bridge over the Peace River near Taylor BC (1942 to 1952)

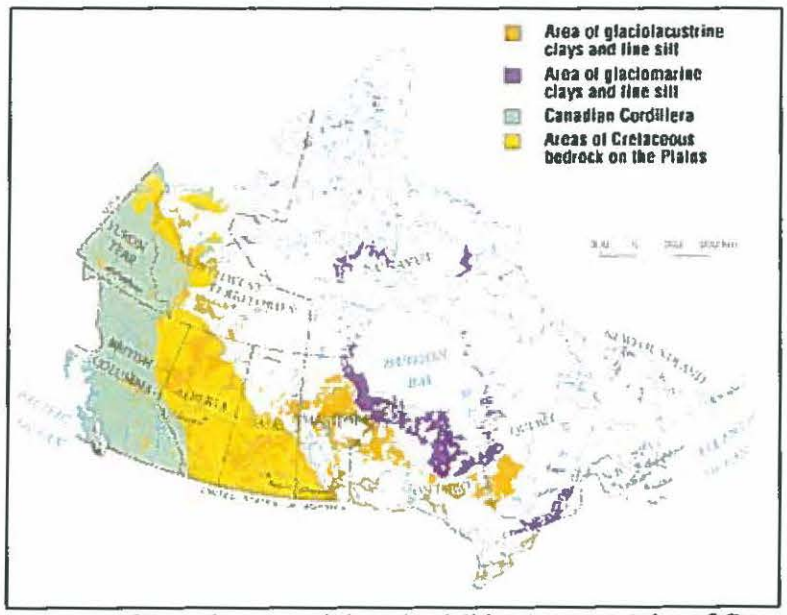
Movement of the bridge's north abutment was first noticed in 1952. A survey was conducted to monitor this movement. The survey was re-done in early October 1957 following a season of higher than normal precipitation (rain and/or snow). The survey showed that bridge structures at the north end of the bridge had moved. Cracks in the road leading to the bridge were also noticed. On October 15, 1957, an alert truck driver noticed unusual settlement in the road. Upon inspection, the army immediately closed the road. Throughout that evening, slow but continuous movement of bridge structures were observed. By just after noon on October 16, the bridge collapsed.

Later investigations found that the bridge failed due to a landslide in the shale bedrock beneath the bridge. A landslide is the down-slope movement or rock or sediment under the influence of gravity. The landslide was about 330 metres wide and extended some 35 metres off shore. The offshore extent of the landslide was indicated by a pressure ridge that stuck out above the water. A pressure ridge looks similar to a ridge pushed up by a bulldozer.



A landslide destroyed the bridge on October 16, 1957. The landslide was in Cretaceous shale.

At the time of construction, little was known about the problems with building on the shale rock type found in the region. Geologists call this shale the Shaftesbury Formation. The shale began as mud that was deposited on a sea floor during the Cretaceous period (65 to 144 million years ago), when dinosaurs walked the earth. At that time an inland sea occupied a large portion of North America. With time, the mud eventually became rock (shale). However, these rocks are very weak and quickly turn back into mud when they are near the surface and when they are exposed to water.



Major areas of Canada susceptible to landslides (source: Atlas of Canada)

Valley slopes in the Peace River region are susceptible to landslides because of the nature of the rocks and sediments that are found in the area. Building in the valleys can make this situation worse. It is now believed that deterioration of the stability at the site of the Peace River bridge likely began soon after the bridge was first constructed and continued for a number of years afterwards. However, the final trigger for the landslide was probably high precipitation.

More to Explore

Hardy, R.M. 1963. The Peace River Highway Bridge – A Failure in Soft Shale. Highway Research Record, 17, pp. 29-39.

Thomson, S. 1958 (May). Collapse of the Peace River Bridge. The BC Professional Engineer, Journal of the Association of Professional Engineers of BC, pp. 13-15.