Site C Backgrounder for Peter Kent

Site C Announcement:

"Liberals issue go-ahead for $6.6 billion Site C dam" by Scott Simpson, Vancouver Sun: Monday, April 19, 2010

> *Premier Gordon Campbell announced Monday that his government plans to move forward with the proposed $6.6 billion Site C dam project on the Peace River.*
>
> *http://www.vancouversun.com/story_print.html?id=2925303&sponsor=*
>
> *http://www.globaltvbc.com/technology/Decision+looms+billion+Site+project/2924668/story.html*

There seems to be some engineering challenges, otherwise how did this project become the most expensive 900 megawatt hydro project on the planet?

For example the Lower Churchill (Muskrat Falls) project in Labrador is a 6 billion dollar effort but those costs are for an entire distribution network that includes not one but two significant ocean crossings. The dam/generating station is a projected $2.9 billion which is less than half the Site C cost. The Lower Churchill is an 824 Megawatt facility while Site C is only 900. If we look at BC Hydro's own numbers, the average projected output for Site C is approximately 550 megawatts. Manitoba's Conawapa project is half again the size of Site C but far less expensive per megawatt. The same for the Romaine River hydro project in Quebec.

The following excerpt provides information on the Lower Churchill.

> *… with a $6.2-billion deal to develop the Lower Churchill hydroelectric project in Labrador*
>
> *Under the term sheet announced Thursday, Newfoundland and Labrador's Crown utility, Nalcor Energy, would spend $2.9 billion to build a power generating facility at Muskrat Falls capable of producing 824 megawatts of electricity.*
>
> *http://www.globallethbridge.com/Newfoundland+announces+massive+energy+deal/3848716/story.html*

The defined costs on this include $2.9 billion for the generating station that has an output of 824 megawatts, i.e., $3.52 million per megawatt installed capacity.

According to Manitoba Hydro, Conawapa has a maximum stated capacity of 1485 MW. This translates to $3.37 million per megawatt cost of installation.

> *The Conawapa Generating Station would be the largest hydro-electric project ever built in northern Manitoba. It would add 1485-megawatts to the hydroelectric system… The estimated in-service cost of the generating station is $5 billion.*
>
> *http://www.hydro.mb.ca/projects/conawapa.shtml*

Hydro-Quebec's hydroelectric project on the Romaine River works out to $4.2 million per megawatt of installed capacity.

> *Hydro-Quebec Launches Four-Dam Project on Romaine River 06/17/2009.*
>
> *Hydro-Quebec broke ground last month for its Romaine Complex, a $6.5-billion hydropower project comprising four rockfill dams on the Romaine River, ranging in height from 34 m to 114 m and generating a total of 1,550 MW.*
>
> *http://enr.construction.com/infrastructure/water_dams/2009/0617-hydroquebecdam.asp*

These all lay far shy of BC Hydro's initial estimates of $7.33 million per megawatt of installed capacity.

Jim Prentice's quote:

From the article entitled "Canadian, U.S. energy policy to be inextricably linked: Prentice" by Richard Blackwell, Globe and Mail, Jan 20th, 2009,

> *While geothermal, wind and solar power are important, the best bet for clean power is more hydro-electric development, he said.*
>
> *http://www.theglobeandmail.com/report-on-business/canadian-us-energy-policy-to-be-inextricably-linked-prentice/article966698/*
>
> *http://www.theglobeandmail.com/servlet/story/RTGAM.20090120.wprentice0120/BNStory/energy/*

Yet, what Mr. Prentice doesn't seem to realize is that all dams are not created equal.

All Dams are Not Created Equal - Unstable Geology of the Peace Valley:

Landslide Concerns:

There has been some acknowledgement of the unstable geology of the area by BC Hydro but yet much uncertainty remains when it comes to the geomorphology of the region in regard to impacts of Site C.

According to an article "Initial geotechnical study on Site C completed" in the Alaska Highway News (Feb. 26th, 2011),

> *The Valley's steep slopes and unstable banks make it prone to landslides, like the one that blocked the river at Attache Creek in 1973.*
>
> *Because of this, the engineers analyzed specific slopes like those opposite of Bear Flat, the riverbank along Hudson's Hope, and at Farrell and Lynx Creeks.*

Engineer Andrew Watson, admitted that a lot of uncertainty surrounds how the valley will respond to a new reservoir.

One concerned resident pointed out that the word, uncertainty, was used 22 times in a 2003 analysis of the valley and classified the project as posing a high risk for its geological instability.

Watson admitted that the valley is unlike any others in B.C. and that a risk does exist but emphasized that the valley is still a safe place for a reservoir.

"The real question is how do we manage that uncertainty?" said Watson.

http://www.alaskahighwaynews.ca/article/20110226/FORTSTJOHN0101/302269998/-1/fortstjohn/initial-geotechnical-study-on-site-c-completed

Potential hazards were outlined by Andrew Watson, the lead project engineer for BC Hydro,

Watson says one of the hazards that might affect the dam's production include a risk of landslides. Such landslides at the construction site could occur rapidly, from various heights of the high river bank, due to the instability of certain slopes in the area.

Watson also says there is a very real possibility of shoreline erosion, which is a factor in the potential for landsides. He says that the quality of an area's soil is important when considering a specific construction site.

from "Site C seminar outlines potential hazards", http://energeticcity.ca/fortstjohn/news/02/24/11/site-c-seminar-outlines-potential-hazards

There have been 4 major slides as outlined in a BC Hydro report (Peace River Development Site C Project: Review of Upstream Axes)

Since the beginning of the century the following significant slides are known to have occurred in Site C:

- *In the early 1900's, movement or reactivation of the Cache Creek Slide at Mile 51 (Site C is located at about Mile 39, measured from BC-Alberta border).*
- *In 1957, failure of the north bank at Taylor Flats resulting in collapse of the previous highway bridge. The slide occurred in shale.*
- *In 1973, the Attachie Slide on the south bank at Mile 62. The slide occurred in the overburden and blocked the river for 10 hours.*
- *In 1974, failure of the north bank at Mile 31, cutting off the B.C.R. main line. The slide occurred in overburden.*

http://www.bchydro.com/etc/medialib/internet/documents/policies/pdf/sitec_01_peace_site_c_review_of_upstream_axes_kcb_pdf.Par.0001.File.sitec_01_peace_site_c_review_of_upstream_axes_kcb.pdf

It is questionable whether such an unstable shoreline could even support a 60 m high earth-filled dam... there is no bedrock in sight at the proposed location to anchor it to.

Another very real concern is the potential for a large landslide-induced wave overtopping the crest of the dam. If a wave crested the dam, being earth-filled, it could cause a breach.

In the same report (Peace River Development Site C Project: Review of Upstream Axes),

> *"Landslides have played a significant role in the development of the Peace River Valley. Some of the valley slopes are marginally stable and there are many historic and currently active landslides."*
>
> *"The inherent slope instability is a significant issue for the construction of a dam."*
>
> *http://www.bchydro.com/etc/medialib/internet/documents/policies/pdf/sitec_01_peace_site_c_review_of_upstream_axes_kcb_pdf.Par.0001.File.sitec_01_peace_site_c_review_of_upstream_axes_kcb.pdf*

A major concern is reactivating old slides. In particular, the Halfway river is the most significant contributor of silt. The close proximity of the Halfway river to the old Attachie slide is problematic. It is likely that significant silt deposition will occur at this locale and this could easily result in a narrowing of the proposed reservoir at this location and undercutting of the opposite bank.

What is perhaps of greatest concern is the vast amount of uncertainty that remains following the geotechnical studies.

From Peace River - Site C Hydro Project Reservoir Shoreline Impacts Methodology and Criteria. Report No. P05032A02-10-001

Page 9; Klohn Crippen Berger Ltd. and SNC-Lavalin Inc. September 2009.

> *"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."*
>
> *http://www.bchydro.com/etc/medialib/internet/documents/planning_regulatory/site_c/2010Q2/peace_river_site_c13.Par.0001.File.Peace_River_Site_C_Hydro_Project_-_Reservoir_Shoreline_Impacts_-_Methodology_and_Criteria.pdf*

From the Thurber Report, 1976

PHOTO 6-7. *Looking southward across the Peace River at the Attachie landslide (Mile 63). The slide occurred on 26 May 1973 and its debris blocked the river for approximately 10 hours. It illustrates a rotational slide in overburden overlying shale bedrock.*

PHOTO 6-8. *Looking southward over the Pine River toward a large slide in bedrock approximately one mile across. The slide occurred in shale of the Shaftesbury Formation. A similar slide 1.5 miles across and 1500 feet high occurred on the north bank of the Peace River downstream of Cache Creek.*

Sites C and E Hydroelectric Development Proposals: Lower Peace River Environmental Study. Sept. 1976. Volume II: Impact Assessment of Basic Alternatives – Part of a Report to BC Hydro and Power Authority

The Attachie slide involved the slump of a huge amount of sediment, just a fraction of which entered the river. Had a reservoir been in place at full pool, a much greater portion of this 24 million cubic meters of sediment would have been trapped within the reservoir.

From Ministry of Forests, Mines and Lands website:
http://www.empr.gov.bc.ca/MINING/GEOSCIENCE/SURFICIALGEOLOGYANDHAZARDS/LANDSLIDES/Pages/Wheredolandslidesoccur.aspx

> *Some areas of British Columbia are more susceptible to landslides than others because of their unique geological conditions:*
>
> *Thick clay and silt-rich glacial sediments in the* ***Northeastern Plateau*** *are prone to soil creep and are frequently undercut by rivers, which results in slumps.*
>
> *1973 Attachie Slide/Fort St. John Clay slump*
> *Over 24 million cubic metres of sediment*

> *The Attachie slide of May 26, 1973 west of Fort St. John dammed the Peace River for approximately 10 hours (photo courtesy of Thurber Engineering Ltd.)*

"Contrasting failure behaviour of two large landslides in clay and silt" by Lara Fletcher, Oldrich Hungr, and S.G. Evans, Can. Geotech. J. 39: 46–62 (2002)

> *[the Attachie slide] suddenly developed into an extremely rapid flow slide of 6.4 Mm3[million cubic meters], damming a large river in the course of a few minutes and projecting a wave onto the opposite bank. The flow slide followed a period of strong infiltration.*
>
> *Extensive glaciolacustrine sediments have been deposited along river valleys of British Columbia and Alberta… Subsequent glacial overriding has overconsolidated the laminated silt and clay.*

These sediments are subject to widespread slope instability where oversteepening, stress release, and valley rebound associated with fluvial erosion have taken place.

… two landslides of this kind, the Attachie landslide on the Peace River in northeastern British Columbia… both occurred in heavily overconsolidated, laminated clay and silt, which was once overridden by as much as 2000 m of glacial ice. They had compound surfaces of rupture, consisting of a weak, shallow-angled plane, on which the body of the displaced mass moved in a translational manner, and a steep main scarp. In both present cases the surface of rupture daylights high on the bank above a river and is underlain by pervious strata of sand and gravel. Both involve volumes measured in millions of cubic metres.

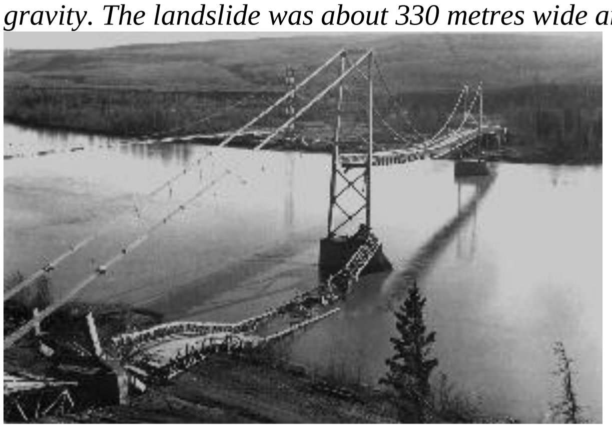
Then, on 26 May 1973, a major flow slide was triggered (Evans et al. 1996). More than 50% of the total volume of the failing mass started moving suddenly and formed a flow slide of 6.4 Mm3 which descended a 50 m bedrock scarp and travelled nearly 1 km to its distal limit on the opposite side of the Peace River floodplain (Fig. 6). The debris generated a displacement wave that downed trees on the opposite bank and blocked the flow of the Peace River for about 10 h (Evans et al. 1996). Local inhabitants reported that noises generated by the slide lasted over a period of only 10 min (Thurber Consultants Ltd. 1973). This type of extremely rapid flow slide failure is not the usual mode of movement in insensitive, overconsolidated glaciolacustrine sediments.

http://article.pubs.nrc-cnrc.gc.ca/ppv/RPViewDoc?issn=1208-6010&volume=39&issue=1&startPage=46

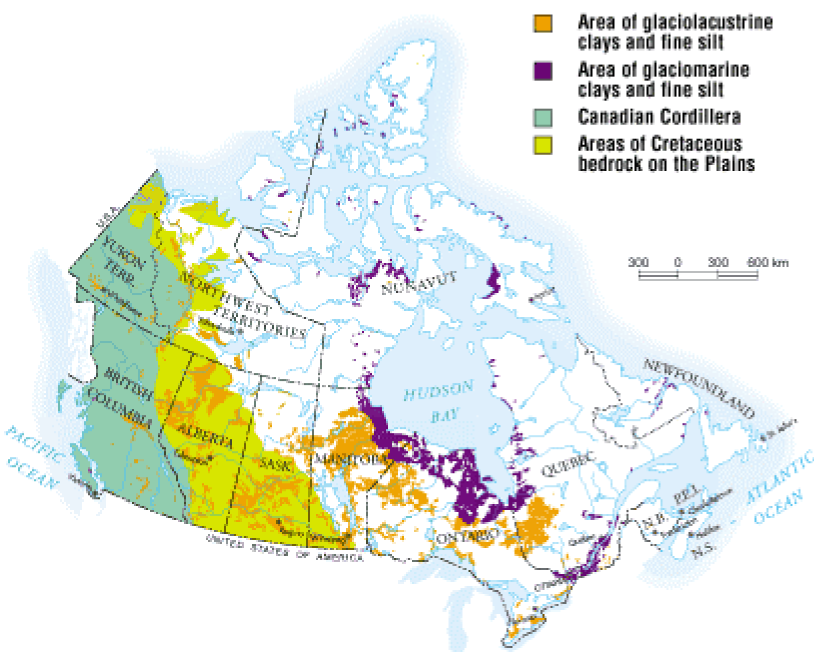
From the article entitled “The 1957 Peace River Bridge Collapse, Taylor BC” by the Association of PROFESSIONAL ENGINEERS AND GEOSCIENTISTS of the Province of British Columbia, PEACE RIVER BRANCH

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.

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 landslide was in Cretaceous shale….
Geologists call this shale the Shaftesbury Formation….
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.



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.

http://www.apeg.bc.ca/services/branches/documents/pr/Peace_River_Bridge_Collapse.pdf

Similarities with the Peace River valley can be drawn to other locations in which dams have been problematic.

Teton Dam in Idaho failed during the filling of the reservoir. This area is similar in geology to the Site C location in that both involve unstable soil structures.
http://en.wikipedia.org/wiki/Teton_Dam#Geology

When Teton Dam failed, the reservoir was 270 feet deep (at the dam) and drained in less than six hours. The filling and the subsequent rapid draining of the reservoir triggered more than 200 landslides in the river canyon that was inundated by the former reservoir.

http://www.usbr.gov/pn/about/Teton.html

In the case of Vajont Dam in Italy, filling the reservoir caused geological failure in the valley wall leading to a 110 km/h landslide into the lake with water escaping in a megatsunami. Strictly speaking, this could not be classified as a dam failure since the dam structure didn't collapse at all. Rather, the Vajont Dam was breached by a massive wave (1963).
http://en.wikipedia.org/wiki/Dam_failure

Similarly, the region surrounding the Vajont dam had geological instability.

> *October 9, 1963, the lives of 2500 people were washed away in minutes as massive waves spilled over the concrete arch dam into the Longarone Valley in Italy. Completed in 1961, the dam created a landslide into its reservoir that generated a wall of water that destroyed the surrounding towns.*
>
> *http://www.history.ca/ontv/titledetails.aspx?titleid=79111*

The following sounds strikingly similar to the Peace River Bridge collapse of 1957.

> *It is now generally agreed that failure occurred along bands of clay within the limestone mass. Persistent rainfall shortly before the catastrophic failure may also have contributed significantly to the maintainement of elevated water pressures (HENDRON & PATTON, 1985). Collapse has been considered either as the reactivation of a relict landslide (HENDRON & PATTON, 1985; SEMENZA & GHIROTTI, 2000; SEMENZA, 2000;) or as a first-time landslide (SKEMPTON, 1966; MÜLLER, 1968). Dynamic analysys attributes rapid collapse to unusual mechanisms, such as the vaporization of ground water during sliding (VOIGHT & FAUST, 1982; ANDERSON in HENDRON & PATTON, 1985; NONVEILLER, 1992), the decrease in clay shear strength with increasing strain rate (TIKA & HUTCHINSON, 1999), or else to self-accelerating rocks producing an abrupt drop in resisting stress.*
>
> *http://www.vajont.info/gGeoAppl.pdf*

Some parallels can also be drawn to dams in Japan. The following article entitled "The Immense Cost of Japanese Dams and Dam-Related Landslides and Earthquakes" provides clear consequences of dams built in regions prone to landslides and earthquakes.

> *Tokyo University Professor Konagai Kazuo appeared on NHK television's "Close-up Gendai" special, "The Mountain that Disappeared: The Iwate-Miyagi Nairiku Earthquake," and explained that because ground water near the dam was high and because snowmelt had permeated the ground, the violent shaking of the earthquake had caused the massive landslide. …*
>
> *In Japan, the government has only recently reached the point where it is finally willing to recognize the causal relationship between reservoirs and landslides. The Ōtaki Dam in Nara Prefecture was completed in 1977 after over two decades of construction, the expenditure of 23 billion yen, and the relocation of 475 households located mainly in the village of Kawakami. After years of extension, in March 2003, workers began to fill the reservoir up with water. The following month, a slope to the right of the dam in an area known as Shiroya began to creep downward. As the president of the neighborhood community association, 75-year old Isaka Kanshiro, recalls, "In the middle of the village, a crack appeared in the ground, and it was clear*

that it was very deep."

There was good reason that Isaka, who is not a geologist, came to this conclusion. "Before the dam was constructed," Isaka remembers, "The government had determined based on soil surveys that the areas of Shiroya and Hitochi (which sits below Shiroya next to the reservoir) were in danger of landslides." Researchers concluded that the slide was 70 meters deep and recommended that all the households in the village be moved to a safe location.

This did not happen, though. According to Isaka, "Government officials decided that the village did not need to be moved if certain measures were taken to prevent the land from sliding. But once they began to design the dam, they decided that because there was no evidence of sliding at the 70 meter level it would be okay and that taking measures so deep would cost a tremendous amount of money. So instead they drove some piles into the ground 20 meters deep. This was like beating the air. We did not agree with this, and when they started filling up the reservoir and the water level rose, of course the land slid."

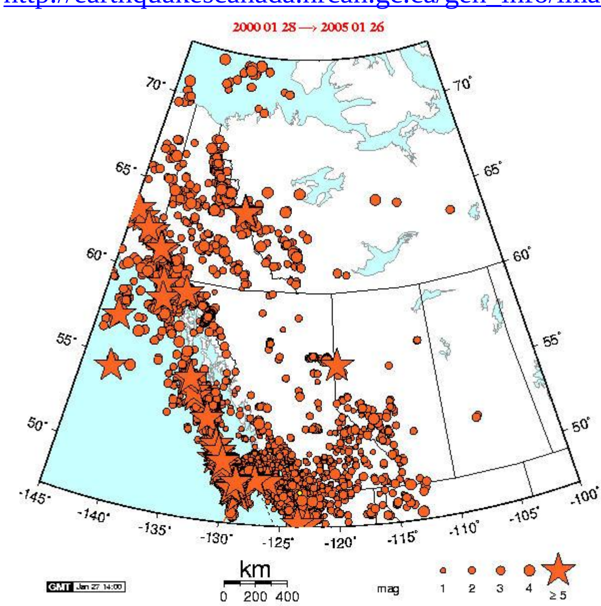
Soon thereafter, the Construction Ministry "recognized that the damned water was the cause" of the landslide. In May 2003, the ministry created a committee to investigate the fissure in the Shiroya area, which cited other precedents of reservoirs triggering landslides such as Ōdo Dam in Kochi Prefecture in 1982, Hachisu Dam in Mei Prefecture in 1991, and Vaiont Dam in Italy. The Construction Ministry was clearly aware of the dam-caused landslides. …

According to Isaka, "As the water level rose to 305 meters on its way to the capacity of 320 meters, the fissure occurred. If the ground had shifted a month later (when the water level was higher), the entire village would have slipped into the reservoir."

http://www.japanfocus.org/-Masano-Atsuko/3280

Seismic Concerns:

http://earthquakescanada.nrcan.gc.ca/gen_info/images/wc.5yr.jpg



According to Natural Resources Canada,

Northern Cordillera
The northern Rocky Mountain region is one of the most seismically active areas of Canada.

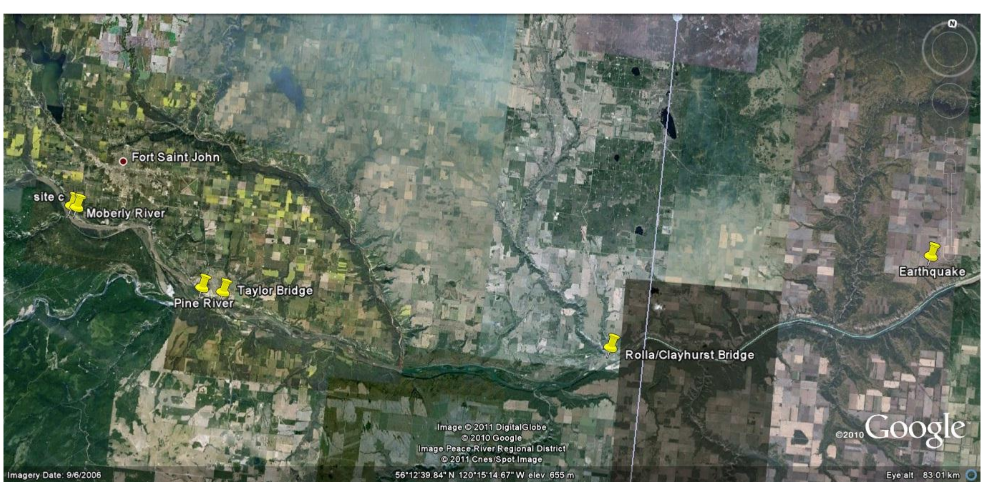
http://earthquakescanada.nrcan.gc.ca/zones/westcan-eng.php

Earthquake Information	
Friday April 13, 2001	
Local Time:	**20:20:13 MDT**
Magnitude:	**5.4 Mw**
Latitude:	**56 North**
Longitude:	**119.74 West**
UT Date and Time:	**2001-04-14 02:20:13 UT**

This indicates the location being along the Peace River, downstream of the Rolla/Clayhurst bridge.

Near Dawson Creek, B.C.
Felt from Edmonton, AB. to Prince George and Fort Nelson, B.C.

http://earthquakescanada.nrcan.gc.ca/recent/2001/20010414.0220/index-eng.php



Silting concerns:

If the Site C project were to proceed to construction, the sediment currently contributed to the Peace River from the newly regulated area (between Peace Canyon Dam and Site C) and related tributaries would be trapped in the reservoir (~3 million tonnes/year).

http://www.bchydro.com/etc/medialib/internet/documents/planning_regulatory/site_c/2010Q2/peace_river_site_c20.Par.0001.File.Peace_River_Site_C_Hydro_Project_Stage_2_-_Review_of_Potential_Downstream_Changes_from_Site_C_Operations_-_Preliminary_Findings.pdf

This is a significant increase from the estimates detailed in their 2003 report as follows.

"Prefeasibility Study for a Cascade of Low Consequence Structures as an Alternative to Site C", starting on pg. 2-3 (or 17 as a pdf)

The Halfway River is the largest single sediment source with an annual average contribution of 2.3 million tons (B.C. Hydro, 1976). The distribution of size fractions in the Halfway River sediment load is as follows:

- *Sand – 10%*
- *Silt – 45%*
- *Clay – 45%*

Assuming that the clay fractions would remain in suspension in the relatively small reservoirs of the Peace Cascade Development, the sand and silt fraction (55% of the sediment load) has the potential to settle in the reservoir. The sediment densities given in the river morphology study (BC Hydro, 1976) were used to convert the sediment weights to an annual average volume of material. From the Halfway River alone, the volume of sediment with a potential to cause sedimentation was found to be approximately 0.9 million m^3/year.

http://www.bchydro.com/etc/medialib/internet/documents/policies/pdf/sitec_04_kcpp1448_peace_cascade_pdf.Par.0001.File.sitec_04_kcpp1448_peace_cascade.pdf

It should be noted that the prediction that only 55% of the load would settle out was based on a cascade structure with a much smaller reservoir and less disturbance of flow. It would be significantly greater for the Site C design with a 21 day turn-over in water supply. ("Site C Document" by Dennis Ableson in the Outdoor Edge British Columbia, pg 33, Nov/Dec 2010.)

Site C has often been referred to as Gordon Campbell's legacy project with claims of providing power for over 100 years. The benefits of generating 30 per cent of the electricity produced at the W.A.C. Bennett Dam with only five per cent of the reservoir area have often been stated by proponents (http://theleftcoast.ca/?p=1168). However, they fail to mention several very important points.

Former BC Energy Minister Blair Lekstrom has said on several occasions that the Site C reservoir will be a pressure head reservoir only, not a water storage reservoir. Thus, Site C will be almost entirely dependent upon water from the Williston Reservoir behind the W.A.C. Bennett Dam. BC Hydro, former premier Gordon Campbell, and Former Energy Minister Blair Lekstrom have all said that Site C will provide clean energy for more than 100 years. If Site C were completed tomorrow that would suggest that the W.A.C. Bennett structure would also have to remain functional for at least 100 more years. It is already 43 years old and in only its 28th year had begun to show signs of internal erosion.

There are no examples anywhere that can be used to reference large earth-filled dams with life spans even close to that length.

An interesting quote from Dave Cobb**,** BC Hydro President & CEO, suggests there is in fact a lifetime on these dams as one would reasonably expect.

> *"The most significant cost factor driving rate increases is our ongoing capital investment program as we continue a regeneration phase at BC Hydro," Cobb claimed. "Our dams, generating stations and transmission lines were built primarily between 1950 and 1980, and many of these assets are nearing their end of life."*
>
> *http://www.straight.com/article-379477/vancouver/hydro-hike-linked-trickery*

It has been stated that the Site C reservoir will be only 5% of the size of the Williston Reservoir in area. However, it will be considerably less than 5% in volume (the maximum depth of Williston approaches 175 meters in places while the proposed reservoir for Site C would be more on the order of 55 meters).

This significantly smaller size also makes Site C far more susceptible to early filling by silt than its larger neighbour. Disregarding future landslides/sloughing, Site C is expected to take on approximately three million metric tonnes of silt per year after construction is complete. Each year this happens it will reduce the ability of the reservoir to hold water. As reservoir capacity decreases, it logically follows that there would be an accompanying reduction in the dam's ability to handle unexpected events such as once in a hundred year floods or landslide displacements of water.

It is important to note that although geotechnical work has involved modelling of potential waves produced by landslides, that work was done considering initial conditions. To the best of our knowledge and based on personal communications with BC Hydro engineers, this modelling has not been done on a silt-filled reservoir.

> *The hazard presented by landslides involves not only failure of ground beneath a structure and the impact or burial of moving debris, but also such secondary effects as landslide-dammed floods and landslide-generated waves.*
>
> *http://atlas.nrcan.gc.ca/auth/english/maps/environment/naturalhazards/landslides/1*

Given that one of the leading causes of failure in earth-filled dams is "topping" where a wave or high water goes over the dam and erodes it, reservoir ability to handle change is an important consideration.

Silting is a major issue on many large and well known hydro installations.

Tarbela dam in Pakistan is a notable one with silt issues.

> *From the initial storage capacity of 11.62 MAF [million acre feet] in 1974, it has now reduced to 5.51 MAF in 2005 (i.e. 47% of initial capacity) due to silting.*
>
> *http://www.pakistanpaedia.com/mega/tarbela_dam.html*

There is a great deal of disagreement as to the rate of silt build-up behind the Glen Canyon Dam in Arizona and its effects. No one denies this is an issue, only the timeframe under consideration is up for debate.

> *The primary failure mode for Glen Canyon dam will undoubtedly be an overtopping one spring caused by insufficient storage capacity (either a huge inflow, bigger than 1983, or insufficient storage capacity because the lake was too full of either water or sediment).*
>
> *http://en.wikipedia.org/wiki/Risks_to_the_Glen_Canyon_Dam#Siltation*

Another point of view, http://www.gcrg.org/bqr/16-1/future.html

Silt issues for the Three Gorges Dam in China are well documented.

> *Extraordinary steps have been taken to reduce silt contributions to the Three Gorges reservoir. These include physically removing silt using machinery and building upstream "silt trap" dams.*
>
> *http://www.chinadaily.com.cn/china/2008-08/15/content_6937119.htm*

Potential for Catastophe:

A quote from BC Hydro's own reports (Prefeasibility Study for a Cascade of Low Consequence Structures as an Alternative to Site C) says,

> *"W.A.C. Bennett Dam is classified as a Very High Consequence Category dam, the failure of which would cause significant damages and potentially loss of life. A failure of Bennett Dam would likely cause failure of all of the dams downstream."*
>
> *"High water may destabilize valley slopes"*
>
> *"[Site C] would also fall in the "High" or "Very High" Consequence Category as defined by the Canadian Dam Association because of the potential damage downstream in the event of a dam breach and the economic loss as a result of a dam failure"*

From the Canadian Dam Association,
"Incremental Consequence Classification Methods, Tools and Challenges", October, 2002

> *Table 1: Classification of Dams in Terms of Consequences of Failure:*
>
> *Potential Incremental Consequences of Failure... in terms of Life Safety and in terms of Socioeconomic, Financial and Environmental.*
> *v.high... large number of fatalities... extreme damages, respectively.*
> *high... some fatalities.... large damages...*

According to a paper entitled "DAM RISK MANAGEMENT" by Raymond A. Stewart, Director of Dam Safety, BC Hydro,

> *Risk = Probability of dam failure per year x consequences of realized failure. …*
>
> *Usually the failure probability is estimated or "judged" (although it is arguable that judgement is being exercised) very low, and the consequences very high. Therefore the large uncertainties pervading both failure probability and consequences result in wide bounds on any risk estimates.*
>
> *… Risk Management is "the systematic application of management policies, procedures and practices to the tasks of analyzing, evaluating, controlling, and communicating about risk issues." (CSA, 1997).*
>
> *http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.116.1576&rep=rep1&type=pdf*

Sinkholes at WAC Bennett Dam:

"Detection and Assessment of Internal Erosion at WAC Bennett Dam" by Steve Garner, BC Hydro

•2.5 m diameter at crest
•7 m deep sinkhole
•extremely loose zone to 80 m depth
•variable zone to 125 m depth

•Conventional instrumentation can detect internal erosion
•Conventional instrumentation can accelerate internal erosion

http://www.swedcold.org/Text/WORKSHOP%202006/Session%201/1420%202006-09-11-WORKSHOP-SteveGARNER.pdf

A report of the alarming situation is as follows:

Sinkholes in an earthfill dam signal erosion within the structure. Calls of alarm went out immediately and communities downstream prepared for evacuation. Round-the-clock dam monitoring and surveillance were set up and a sinkhole investigation team was assembled. Torrents of water were released to lower the level of the reservoir, representing a loss of generating capacity of more than $1 million per day. Local newspapers and television stations carried the story of possible disaster if the dam was to let go. It was feared that the entire downstream valley could be wiped out. A second sinkhole was discovered on September 8, 1996.

It was determined that drilling into the core of the dam would be necessary, something that is unprecedented on a working dam. Should a passage be opened up, the ensuing water flow would likely be impossible to stop and could quickly breach the dam. A drilling method was needed that could rapidly provide a continuous core sample and yet did not require the use of compressed air, water or any type of drilling fluid. The hydraulic pressure created by using drilling fluid could potentially create a fracture which could open up a water passage. A hammer drill had been tried but could not penetrate the dense core of the dam.

from Water Well Journal, 1998, pages 120-123.
http://www.sonicdrilling.com/Flash/website_articles/earthfill_dam_with_photos.pdf

more from the Sonic Drilling engineers,

Sonic "*geotechnical core drilling investigation of a large earthen dam*"

When other methods of drilling failed to produce results as to the cause of two sinkholes at the WAC Bennett Dam, located in northeastern British Columbia, they called Boart Longyear. Concerns ran high for the safety of the inhabitants below the dam with experts stating that if the dam failed, the entire river valley downstream would be wiped out. Engineers and hydrogeologists advised that other methods using water, air, or other drilling additives could cause additional problems by increasing hydraulic pressure inside the core of the dam.

http://boartlongyear.virtual.vps-host.net:8080/web/guest/94

A couple of paragraphs from an award winning article by Anne Mullens are as follows:

> *Unlike a tsunami, the destruction wouldn't simply peak and stop. The pent-up waters of Williston Lake would just keep coming, seeking to return to its natural elevation. The waters would flow for weeks, scouring away communities like Old Fort, Taylor, Peace River, Fort Smith and beyond. The onslaught would back up tributaries and inundate the entire Peace River Basin, flooding Lake Athabaska and Great Slave Lake. The floods could devastate northern Alberta, portions of Saskatchewan and the Northwest Territories all the way to the Arctic Ocean. The death toll could be high; the environmental and structural damage astronomical. Combined with the loss of generating power of the dam, the unprecedented disaster would cost billions of dollars and throw B.C.'s economy into turmoil.*
>
> *"The failure of a large dam has the potential to cause more death and destruction than the failure of any other man-made structure," says Dr. Richard Woodward, an Australian dam engineer who maintains a Web page devoted to dam safety.*

The article also included an interesting quote from Jack Farrell, who was comptroller of water rights for the Ministry of the Environment at the time (he had legislative power to regulate and monitor dams in B.C.):

> *"It worked out well. But I don't think any of us will ever feel completely comfortable with the Bennett Dam again. It must be watched very closely for the rest of its life."*
>
> *http://www.openschool.bc.ca/courses/earth/60-Storey_Crisis.pdf*

The story of the sinkholes also appeared in Canadian Business (April 30th, 1999). The article was entitled "A disaster in waiting?" by A. Nikiforuk. Some notable quotes are as follows:

> *According to engineers, sinkholes are to dams what cancer is to people: big bad news.*

Ray Stewart was the director of dam safety for BC Hydro at the time,

> *Stewart, who acknowledges a breach would be horrendous, frankly explains that a "dam may be called safe, but that doesn't mean it's risk-free." For the time being, at least, he gives the Bennett Dam a much better bill of health than it received three years ago. In other words, the cancer appears to be in remission.*

The article also referred to Allan Johnstone, who was a retired geophysicist living 200 km SE of the WAC Bennett dam.

> *But Johnstone isn't satisfied. In fact, he's convinced that the 31-year-old dam, one of the world's largest, could still break at any moment and wash out much of northeastern BC, as well as most of Alberta's Peace River country. Such an event would kill thousands of people, submerge dozens of communities and amount to what Johnstone calls "a trillion-dollar disaster." As the independent researcher explains, the Williston reservoir is 360 kilometres long and more than*

120 metres deep. Any breach in the bottleneck dam, which is built of sand, silt and gravel, would send "an inland sea tidal wave that would swamp anything in its path," including Johnstone's house, "followed by a month-long flood."

http://search.ebscohost.com/login.aspx?direct=true&db=rch&AN=1797745&site=ehost-live

A release from the Ministry of Environment, Lands and Parks (March 6, 1997) states,

> The Williston Reservoir level was ordered lowered last summer as a precaution after two sinkholes were discovered at the dam. A subsequent investigation found that internal erosion, specifically soil particle movement within the dam core, had occurred. Reduced capacity in the drainage system was also discovered.

http://sunnyokanagan.com/wacbennett/benndam.htm

From Hydroworld,

> "Internal erosion is the second largest cause of failure of earthfill dams worldwide. Damages resulting from internal erosion can lead to expensive remediation. Typical dam safety surveillance consists of visual inspections supported by limited instrumentation. However, internal erosion can become quite advanced before the problem is detected via these means."

http://www.hydroworld.com/index/display/article-display/9076033017/articles/hydro-review/volume-29/issue-2/articles/dam-safety__review.html

It should be noted that W.A.C. Bennett was already showing signs of internal erosion only 28 years after it was completed. The following article in the magazine "Water Power and Dam Construction" makes note of that fact and continues by stating,

> *Latent defects may remain undiscovered until deterioration exceeds a tolerable limit or until loading reaches an unprecedented level, as in extreme floods or earthquakes.*

http://www.waterpowermagazine.com/story.asp?storyCode=2024413

From "**A disaster in waiting?(concerns over the safety of Bennett Dam)"** in Canadian Business, April 30th, 1999,

> *"According to engineers, sinkholes are to dams what cancer is to people: big bad news. As a consequence, BC Hydro quietly assembled a small army of specialists and spent $40 million in the past three years analyzing and repairing the damage."*

“Trends in Tailing Dam Safety” Iain G. Bruce, Clint Logue, Lori-Ann Wilchek
Bruce Geotechnical Consultants Inc., April 28, 1997

> *"The BC Hydro WAC Bennet dam is a recent example of a dam that was constructed to stateof-the-art standards, yet still developed sinkholes on the crest and prompted a dramatic lowering in the reservoir. The cause of the sinkholes appear to be the result of the migrating of fines within the core of the dam. The Teton dam in Idaho failed catastrophically during the initial filling of its reservoir in 1976. The piping failure of the dam was caused by, “...the many combinations of unfavourable circumstances inherent in the situation (which) were not visualized, and because adequate defences against these circumstances were not included in the design” (Dunnicliff et al, 1984)."*
>
> *http://www.bgcengineering.info/BGC_Homepage_Files/Publications/IGB%20Bruce,%20I.,%20Logue,%20C.,%20Wilchek,%20L.%201997.%20Trends%20in%20Tailings%20Dam%20Safety.pdf*

from “CONSEQUENCE BASED SAFETY EVALUATION OF AN EARTH DAM FOR FLOODS AND EARTHQUAKES” by D.N.D. Hartford and J.K. Lou, B.C. Hydro, Burnaby, British Columbia

> *"judgemental") interpretation of probability in assessing the likelihood of occurrence of events for which no statistical data exist or which have no statistical basis. Judgementallyderived probabilities complement those evaluated on a relative-frequency (or statistical) basis, and neither probability axioms nor actual calculations of failure probability from the event trees depend on which interpretation is used. Salmon [2] discusses the logical foundations for various probability interpretations, and Baecher [3], [4] describes the basis for applying judgemental probability to geologic and geotechnical factors in probabilistic risk analysis.*
>
> *Judgemental probability statements for various events ...*
> *a normative convention was established to translate broadly-based verbal descriptions of uncertainty to quantified likelihood statements according to the following:*

Judged Likelihood of Occurrence	***Assigned Probability (P)***
Event is virtually certain	*0.99*
Event is very likely	*0.9*
Complete uncertainty about the event	*0.5*
Event possible but very unlikely	*0.1*
Event virtually impossible	*0.01 (physically)*

There is no such thing as risk assessment certainty.

Williston Reservoir:

2205 ft (672.08 m) - Max Pool
http://www.bchydro.com/etc/medialib/internet/documents/info/pdf/peace_williston_sep2009.Par.0001.File.peace_williston_monthly_report_sep2009.pdf

$70km^3$
http://www.ilec.or.jp/database/nam/nam-29.html

183 m (600 feet) in height
http://www.bchydro.com/community/recreation_areas/w_a_c_bennett_dam_visitor_centre.html

At a height of 600 feet, this amounts to a hydrostatic pressure of 290 psi behind the base of the dam. Pressure is a critical factor when considering internal erosion.

The town of Peace River has an elevation of 320 meters asl.
http://www.ags.gov.ab.ca/geohazards/pdf/pr_buried_valleys.pdf

It should be noted that the water level at full pool is over 350 meters above the town of Peace River, which has already flooded numerous times because of the Peace River from conditions far less severe than a breach in the W.A.C. Bennett dam.

Another relevant quote from this same paper is as follows:

> *The Peace River lowlands of Alberta and British Columbia are one of the most historically active mass movement areas of western Canada. Urban areas such as the Town of Peace River and their associated infrastructure have been, and continue to be affected by, these movements.*

The situation is even worse for Fort Vermilion.

> *The settlement is situated on the southern banks of the Peace River, at an elevation of 255 m (837 ft) to 282 m (925 ft).*
>
> *http://www.worldlingo.com/ma/enwiki/en/Fort_Vermilion,_Alberta*

There are thousands of documents related to this project. All of these could obviously not be included here. However, not a single document has been made readily available to the public that describes the cost allocations or potential risks, financial and physical, that this project is associated with. For further information please contact Andrea Morison at pveacoordinator@gmail.com or 250-785-4711 and she will redirect your enquiry to the appropriate person. We will do our best to find the information requested and its source.