Submission to the CNSC by the Canadian Coalition for Nuclear Responsibility

Regarding the Darlington New Nuclear Project (DNNP)
and the documents provided in support of
siting one of four BWRX-300 reactors
at the existing Darlington NGS site

EIS Environmental Impact Statement
PPE Plant Parameter Envelope

Submitted March 20 2023

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Part 1. Much Ado About Siting.

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1.1 The original Darlington New Nuclear Project (DNNP-1)

Forty-six years ago, the Ontario government announced its decision to build four new CANDU nuclear reactors at the Darlington site. CANDU reactors are pressurized heavy water reactors. Heavy water is used both as coolant (to cool the fuel) and moderator (to slow down the neutrons).

That event marked the end of an era of rapid nuclear power growth in North America. After that date, from 1978 to 2008, the nuclear industry on this continent endured a three-decades-long drought in domestic reactor sales.

It seemed the drought might be ending fifteen years ago when, in March 2008, Infrastructure Ontario issued a competitive Request for Proposal (RFP) for a new nuclear power station in Ontario. Four vendors were invited to participate in the RFP process: AECL (the ACR-1000), Areva (the EPR), Westinghouse (the AP1000), and GE-Hitachi (ESBWR – Economic Simplified Boiling Water Reactor). These are all water-cooled reactors.

GE-Hitachi chose not to participate in the RFP process. Its reactor, the ESBWR, was the only Boiling Water Reactor design in the mix. The three vendors that remained in competition were all offering pressurized water reactors (PWRs using light water as coolant and moderator, or PHWRs using heavy water for those two functions).

In 2009, Ontario Power Generation (OPG) produced an Environmental Impact Statement (EIS) for the Darlington New Nuclear Project (DNNP). **The utility decided that the new reactors, if approved, would be co-located with four existing CANDU reactors that were already on the Darlington site.** Along with the EIS, the utility produced a Plant Parameter Envelope (PPE) document. **No choice of reactor model had yet been made**.

The Darlington New Build of 2008-2009 would have constituted the first order for new power reactors in North America since 1977, had it come to pass. But it didn't. The project underwent a full Environmental Assessment (EA) review in 2011, and Ontario Power Generation (OPG) even received a licence from the Canadian Nuclear Safety Commission (CNSC) to prepare the Darlington site for the new reactors.

Then, in 2014, the Ontario government abruptly cancelled the order for the first two of the four new reactors. Queen's Park balked at the exorbitant price tag, rumoured to be in the ballpark of $14 billion per unit. In the wake of that decision, none of the planned new reactors found their way into OPG's long-term energy plan.

However, OPG insisted that the DNNP New Build project was deferred, not cancelled. The utility ensured that the CNSC licence permitting it to prepare the Darlington site to accommodate new reactors would remain in force until 2022. Then, in 2020, OPG saw to it that the site preparation licence was extended even beyond 2022.

1.2 The current Darlington New Nuclear Project (DNNP-2)

Today OPG wants to use that 12-year old licence to prepare the Darlington site for a smaller reactor that was never under consideration in the first go-around. It is a previously unbuilt General-Electric-Hitachi (GEH) Boiling Water reactor design, the BWRX-300, touted as one member of a gang of "Small Modular Nuclear Reactors" (SMRs or SMNRs).

OPG must now persuade CNSC that the old site preparation licence is still valid, despite altered circumstances, and can be used for this new, unforeseen purpose. To do this, OPG has dusted off two documents that were written in support of the original Darlington New Build Project conceived 15 years ago, involving three completely different reactor designs.

Those documents are:

(1) OPG's 2009 Environmental Impact Statement (EIS-2) report for the original Darlington New Build Project; updated version October 2022.

(2) OPG's Plant Parameter Envelope (PPE-2) report; updated October 2022 (revision #5).

OPG has modified these two pre-Fukushima documents by adding some data relevant to the BWRX-300, without describing the reactor design in any meaningful detail. In the modified PPE, for example, the description of the BWRX-300 reactor design is limited to just three-quarters of a page and one diagram– the very last two pages of PPE-2.

The 2011 EA Report noted that, following a request for OPG to consider other reactor designs, "a revised version of the plant parameter envelope was submitted by OPG on November 30, 2010. OPG noted that a similar **assessment was not performed for a boiling water reactor as insufficient information was available** to allow OPG to do so."

CCNR also finds insufficient information available in the aforementioned documents for our reviewers to do a meaningful analysis bearing on the site preparation licence for the boiling water reactor BWRX-300. Indeed, it appears to us that this entire exercise may be merely a formality – a prelude before CNSC grants OPG a licence to construct, which seems to be taken by all players as a forgone conclusion.

Just one day after Canada's Infrastructure Bank gave OPG a $970-million "low-interest loan" to develop the BWRX-300 at Darlington, the Minister of Natural Resources Canada boasted to a Washington audience that it would soon be Canada's first commercial SMNR.

Coincidentally, the Minister of Natural Resources (NRCan) is designated as the "responsible minister" in the Canadian Nuclear Safety and Control Act. That's the law establishing CNSC as an agency of the crown, whose mandate is to protect the health and safety of Canadians and the environment from unreasonable radiation exposures, and to disseminate objective scientific information on nuclear matters.

Although the International Atomic Energy Agency (IAEA) has urged that nuclear regulators not be linked to government agencies that promote the nuclear industry, that sensible suggestion does not seem to have been implemented in Canada.

CNSC president Rumina Velshi has publicly lauded the speed at which the BWRX-300 licensing is proceeding, saying that Canada will be the first western country to approve an SMNR built for the grid. She has stated publicly that the CNSC is there to protect people against radiation, not against progress.

CNSC has not yet approved the reactor. However, OPG held a ground-breaking ceremony at Darlington in December 2022. So the licence to construct seems to be a foregone conclusion – to NRCan, to CNSC, and to OPG. In 2017, CNSC freely admitted that from the year of the agency's inception, in 2000, it has never refused to grant a licence for any major nuclear facility.

Government, regulator and industry are already on board. So what is the intended purpose of this review?

On page 5 of the PPE-2 we read: "The concept of a PPE was developed in the United States for use in the Early Site Permit (ESP) process to resolve siting and environmental issues at a particular site **before a reactor design has been chosen**."

However, we have now arrived at the point where a reactor design has been chosen. So the PPE-2 document is actually moot and irrelevant– filled as it is with extraneous information about the three original candidate reactors that have since gone by the wayside. Adding sparse numerical data about the BWRX-300 – data supplied by the vendor, without any detailed design information to allow others to verify or to challenge those data, hardly constitutes a meaningful review process.

Continuing from page 5 of PPE-2: "The PPE concept is also consistent with the Canadian Nuclear Safety Commission (CNSC) statement in Revision 1 of the CNSC Information Document INFO-0756 [R-12]; 'An application for a Licence to Prepare Site does not require detailed information or determination of reactor design; however, **high level design information is required for the environmental assessment that precedes the licensing** decision for a Licence to Prepare Site.'"

It is crystal clear that "high level design information" about the BWRX-300 reactor has never been made available to the public, nor to the Joint Review Panel that reviewed the original EIS and produced the 2011 EA Report. OPG just wants the site approval.

That information vacuum and accompanying pressure to accept the sleight-of-hand of replacing one reactor for three others, inspired the title of this report – Much Ado about Siting.

According to CCNR, both documents – the PPE-2 and the EIS-2 – cannot be considered satisfactory surrogates for the real thing: an actual honest-to-goodness environmental impact assessment of the BWRX-300 reactor itself, sited at Darlington or elsewhere.

The present report, Much Ado About Siting, is based on the professional services of Dr. Gordon Edwards and Dr. Sunil Nijhawan. The report is a critical commentary by the Canadian Coalition for Nuclear Responsibility (CCNR) on the use of the afore-mentioned documents as the basis for a decision-making procedure regarding the siting of up to four new BWRX-300 reactors very close to the four existing co-located CANDU reactors.

Part 1, by Dr. Edwards, deals with the siting question directly, while Part 2, by Dr. Nijhawan, deals with the OPG surrogate documents, especially PPE-2.

In the next two sections it will be shown that the construction of the first of these new BWRX-300 reactors (1 of 4) is intended to take place well within the exclusion boundary of the existing Darlington reactors. CCNR believes that this should not be allowed.

Recommendations:

1. CCNR's main contention is that the present procedure lacks validity given the realities of the post-Fukushima world and the paucity of information provided about the BWRX-300 boiling water reactor – a type of reactor that was never considered in the original EIS.

2. Drawing on the lessons of Fukushima regarding the special vulnerabilities of co-located reactors, CCNR urges that construction of any new reactors within the exclusion zone of the existing DNGS four-reactor complex must be ruled out as against the public interest.

3. In keeping with the CNSC regulatory practice as outlined in PPE-2, OPG should be required to prepare a new environmental impact statement with high level design information about the BWRX-300.

4. The EIS for the BWRX-300 must provide a sufficiently detailed description of the plant's design to allow for independent verification of numerical values that are assigned to various parameters such as source terms. It should not be accepted as a foregone conclusion that the Darlington site is necessarily suitable as compared with other sites.

1.3 Radioactive Emissions from Darlington New Build

Let's consider one of the numbers missing from PPE-2, the total atmospheric release of radioactive noble gases (last entries in tables 4.1 and 4.2). We know boiling water reactors tend to release more radioactive gases into the atmosphere than pressurized water reactors.

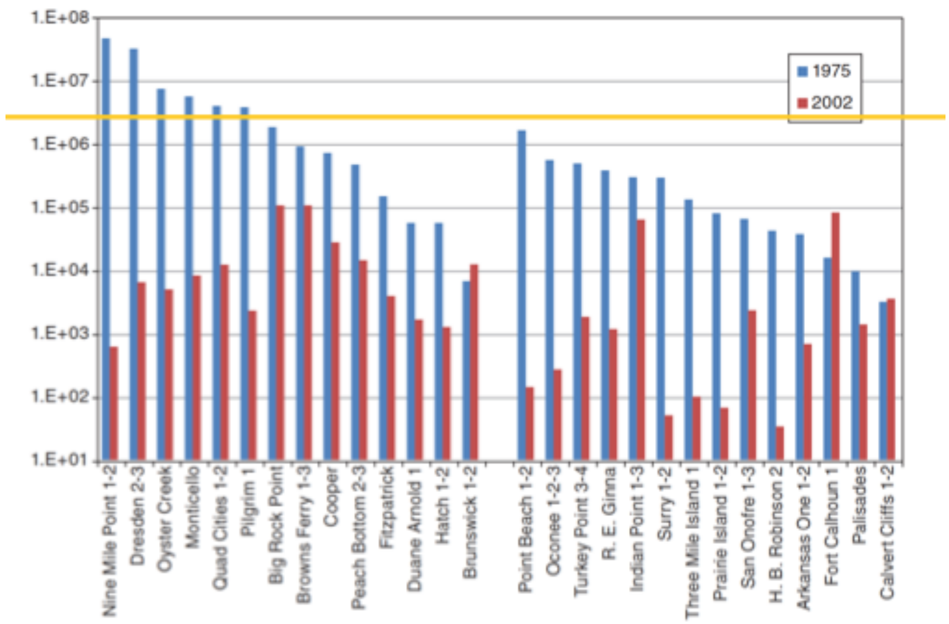


FIGURE 2.5 Comparison of atmospheric releases of noble gases for selected BWRs (left) and PWRs (right) in the United States. The units on the vertical scale are in gigabecquerels (GBq = 0.03 Ci). SOURCE: Data from the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR).

It is troubling that OPG would omit listing the total noble gas emissions in both tables of PPE-2. After all, the BWRX-300 is the only boiling water reactor ever considered in the context of this pre-licensing process.

But even if the appropriate numbers had been given, it would not be enough. You cannot judge the environmental impact of radioactive noble gas emissions just by the number of becquerels released each year. These gases are considerably heavier than air. They have to be released at a great altitude to minimize the gamma dose ("sky shine") to people and animals on the ground below.

But, the BWRX-300 reactor is underground and the building does not reach as high (35 m) as any of the other reactors previously considered in the PPE (typically around 48 m). So the possibility of a near-ground release cannot be excluded. That would be problematic.

There are a great many other considerations surrounding the important topic of radioactive releases. Dr. Frank Greening discussed many such aspects authoritatively in the original DNNP EA hearings of 2011. With his permission, Dr. Greening's original work on this subject is attached as Annex D: "Radioactive Emissions from Darlington New Build." His work should be considered as an integral part of this report.

Dr. Greening's work was originally submitted by le Mouvement Vert Mauricie, along with other reports by Dr. Gordon Edwards and Dr. Michel Duguay, in the original DNNP EA Hearings of 2011. The entire MVM submission is found at www.ccnr.org/MVM_final.pdf

1.4 Fulfilling the JRP conditions

The EIS-2 and PPE-2 documents have been modified by OPG in an effort to include some aspects of the newly chosen design, the GE-Hitachi Boiling Water reactor called BWRX-300. However, very little information about the actual reactor design is given.

Numbers are provided by the vendor without any clear evidence of how they were derived. These numbers are used by OPG to bolster its contention that the GEH BWRX-300 reactor, although never an object of scrutiny during the 2011 EA review, is nevertheless within the scope of that review and therefore acceptable.

As noted earlier, an EA review of the EIS was carried out in 2011. Public hearings were held before a three-person Joint Review Panel (JPR). Two of the Panel members were drawn from the Environmental Assessment Agency and the third from the Canadian Nuclear Safety Commission (CNSC).

The JPR recommended that the EIS be accepted and the project be approved, subject to a large number of important conditions. Approval is given "provided the mitigation measures proposed and commitments made by OPG during the review, and the JRP's recommendations, are implemented."

Those conditions are reproduced in Annex A as a ten-page document.

A great many of the JRP conditions are very specific to the Darlington site. Not only the licensee OPG, but also the regulator CNSC is required to act. Some of the conditions apply "Prior to Site Preparation", some apply "During Site Preparation", some apply "Prior to Construction", and so forth. Here are some examples:

• "CNSC [shall] require OPG to conduct a comprehensive soils characterization program." [Rec. 2];

• "CNSC [shall] require OPG to develop a follow-up and adaptive management program for air contaminants [and] must require OPG to develop an action plan acceptable to Health Canada for days when there are air quality or smog alerts." [Rec. 8]

• "CNSC [shall] require OPG to undertake a detailed site geotechnical investigation prior to commencing site preparation activities." [Rec. 10]

• "CNSC [shall] require OPG to perform a thorough evaluation of site layout opportunities before site preparation activities begin, in order to minimize the overall effects on the terrestrial and aquatic environments and maximize the opportunity for quality terrestrial habitat rehabilitation."

Recommendations:

5. CNSC shall ensure that all of the conditions laid down by the JRP are fully implemented before a construction licence is considered.

6. CNSC shall require OPG to publish, in tabular form, all measures taken to implement each applicable JRP condition and subcondition, with links to appropriate documents detailing how the implementation was carried out. CNSC staff shall certify that the implementations have been satisfactorily realized or that they must be redone.

A particularly important condition is the one dealing with geotechnical aspects of the site:

Recommendation # 38 (Section 5.9):
The Panel recommends that the Canadian Nuclear Safety Commission require that the geotechnical and seismic hazard elements of the detailed site geotechnical investigation to be performed by OPG include, but not be limited to:

Prior to site preparation:

 demonstration that there are no undesirable subsurface conditions at the Project site. The overall site liquefaction potential shall be assessed with the site investigation data; and confirmation of the absence of paleoseismologic features at the site and, if present, further assessment to reduce the overall uncertainty in the seismic hazard assessment during the design of the Project must be conducted.

During site preparation and/or prior to construction:

 verification and confirmation of the absence of surface faulting in the overburden and bedrock at the site.

Prior to construction:

 verification of the stability of the cut slopes and dyke slopes under both static and dynamic loads with site/Project-specific data during the design of the cut slopes and dykes or before their construction;
 assessment of potential liquefaction of the northeast waste stockpile by using the data obtained from the pile itself upon completion of site preparation;
 measurement of the shear strength of the overburden materials and the dynamic properties of both overburden and sedimentary rocks to confirm the site conditions and to perform soil-structure interaction analysis if necessary;
 assessment of the potential settlement in the quaternary deposits due to the groundwater drawdown caused by future St. Mary's Cement quarry activities; and
 assessment of the effect of the potential settlement on buried infrastructures in the deposits during the design of these infrastructures.

OPG contends that BWRX-300 should be accepted as an acceptable surrogate for the three reactor designs that were indeed considered by the Joint Review Panel (JPR), and that PPE-2 and EIS-2 be accepted as acceptable surrogates for the original EIS-1 and EIS-2.

The Canadian Coalition for Nuclear Responsibility does not share this view, as already indicated. Reasons for the CCNR position will be laid out in the following sections.

1.4 Infiltrating the Exclusion Zone

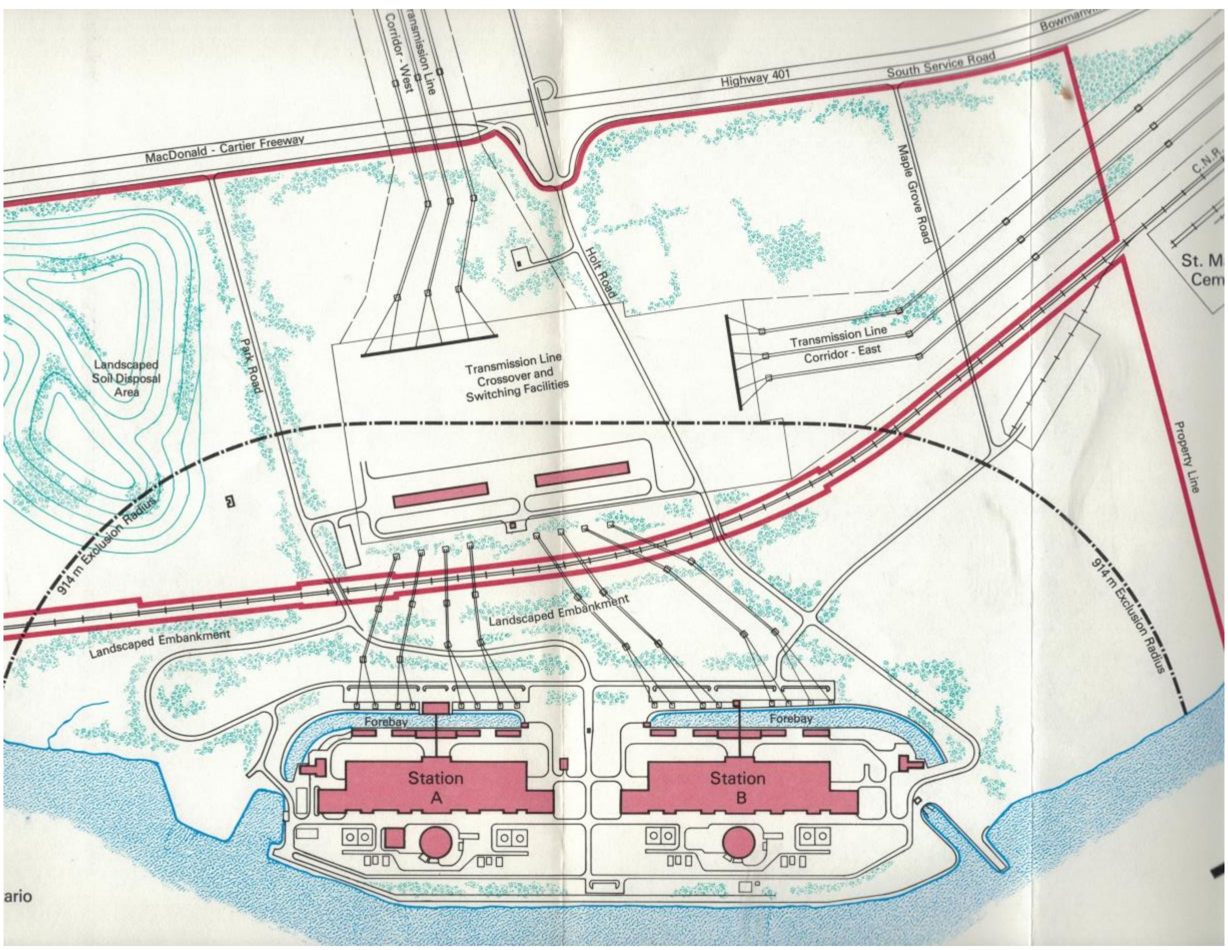
To maintain that the BWRX-300 has essentially been approved "in absentia" by the Joint Review Panel's Environmental Assessment Report of 2011, is unacceptable given
(1) the lack of detailed consideration of the idiosyncrasies of the new reactor choice
(2) the proximity of the Darlington site to Lake Ontario, and
(2) the lessons of Fukushima, which were not available to OPG, the CNSC, the JPR or the Canadian public at the time when the original EIS, PPE and EA report were drawn up.

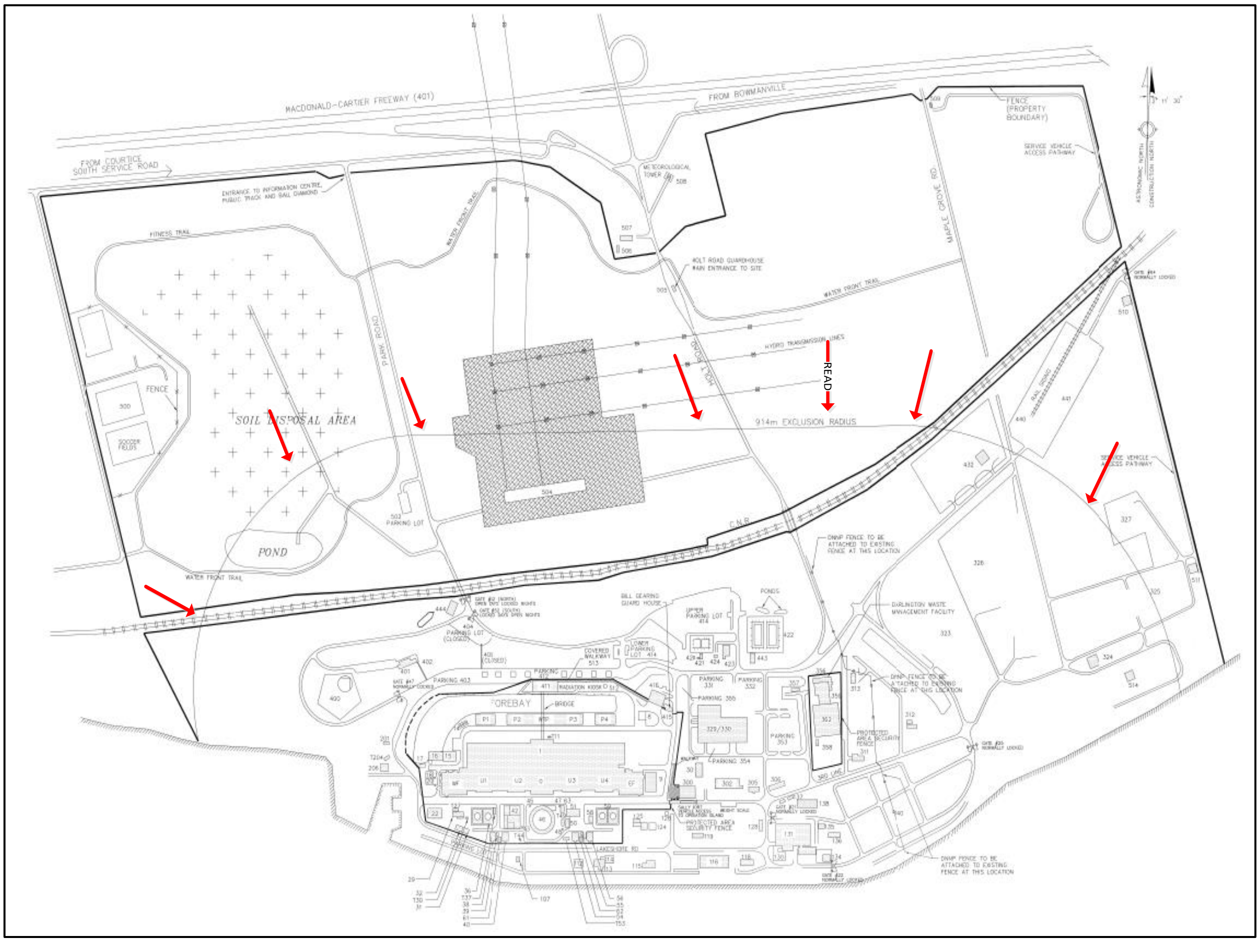
As an example, consider the implications of having the major working portions of a nuclear reactor situated in an underwater chamber, subjected to hydrostatic pressure from all sides. That could be the BWRX-300, if built on the Darlington site. Unlike any of the other three reactor designs considered in the 2009 EIS or the 2011 EA, the BWRX-300 will extend 38 metres underground and well as 35 metres above ground.

Imagine two ten-storey buildings. Each will be about 128 feet tall, or in metric units, 36 metres. Now imagine a ten-storey building turned upside down, going down into the ground, with another ten-storey building going up. Imagine the underground portion to be holding the heart of a 300 megawatt nuclear power reactor. That's the BWRX-300. It is an unusual picture, made more unusual because the underground portion will be in water,

Due to the proximity of Darlington to Lake Ontario, any excavation 38 metres downwards will fill with water very quickly and almost totally, so it will have to be constantly pumped out (dewatered) during construction. Unless dewatering is made permanent – and EIS-2 says it will not be – the hydrostatic pressure on the outside walls of the finished reactor building will be in the range of 300 kilopascals (kPa) at 35 metres depth. That's 6000 pounds (3 tons) per square foot. Yet there is no detailed discussion of the possible implications of such an unprecedented situation in either of the two updated documents, EIS-2 or PPE-2, except for one brief paragraph in EIS-2.

Then there's the geometry. Until the government of Ontario nixed the original DNNP project nine years ago, it was assumed that DNGS A & B (8 large reactors total) would sit side by side. The exclusion zone was designed to accommodate all eight reactors.





In these two images, the dotted lines indicate the boundary of the exclusion zone. The first image is from 1978, the second is from the 2012 Darlington Safety Report.

The DNGS exclusion zone was subsequently redrawn, without commentary, taking in a much smaller area.

Some of the space previously allocated to DNGS B has now been reassigned for the storage of nuclear waste.

The two pictures on the next page are both from 2022. The first image is from OPG's documentation supplied for the recent Waste Management Licence extension hearings, the other one is from current DNNP documentation.

Attachment 5 CD# 00044-CORR-00531-01153

Figure 1: Darlington Site

Note: The blue dotted line in this figure is the DNGS exclusion zone.

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NEDO-33951 REVISION 1
NON-PROPRIETARY INFORMATION

Figure 2.1.1-2: Darlington Nuclear Generation Station and Darlington New Nuclear Project Lands

In each of these two diagrams, green circles represent the boundary of the exclusion zone.

In the aftermath of the Fukushima triple meltdown of 2011, we have a better understanding of the dangers of co-locating reactors. It is perhaps a blessing in disguise that DNGS B never got built. Be that as it may, OPG and CNSC are now considering up to 4 new reactors of the BWRX-300 variety to fit into this rather crowded space, with spent fuel dry storage facilities now occupying some of the space originally intended for DGNS B.

It appears that the first BWRX-300 will be right inside the redrawn DNGS exclusion zone, Its own exclusion zone (circle below, radius 350 m) largely overlaps the one from DNGS.

NEDO-33950 REVISION 2
NON-PROPRIETARY INFORMATION

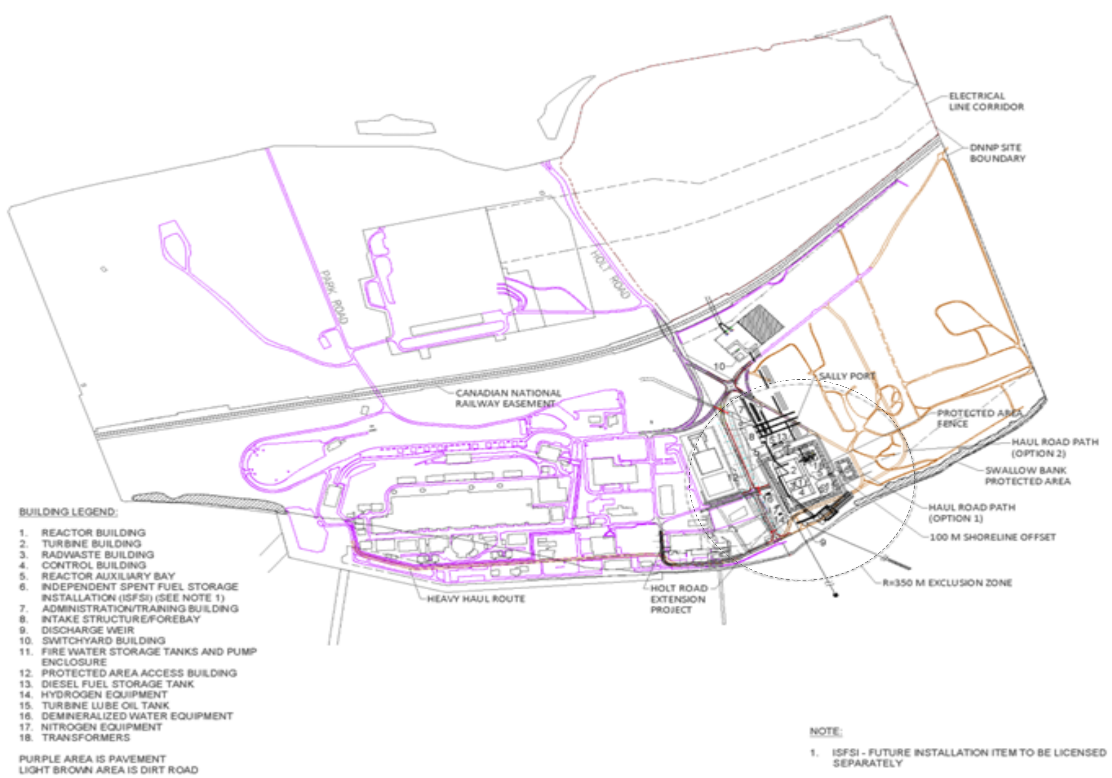

Figure A1.1-2: Darlington Nuclear Site (DNNP Proximity to DNGS)

In light of the lessons we have learned from Fukushima, CCNR believes it is unacceptable to have a new reactor built inside the exclusion zone of an existing reactor. In the event of a severe accident at one or more of the existing Darlington reactors, the entire construction crew of 1,000 to 2,000 workers could receive radiation exposures greater than 25 rems (250 mSv) within two hours. There is no reason to expose the workers to such a risk. They are not even classified as radiation workers.

The exposure of 25 rems in two hours, mentioned in the previous paragraph, is based on the precise definition of an exclusion zone given by the U.S. Nuclear Regulatory Commission (NRC). That definition is explained in the next section. Judging by the rather cavalier way in which the Darlington exclusion zone has been drawn and redrawn, and how the much smaller exclusion zone for the BWRX-300 has been drawn as a perfect circle, CCNR is convinced that CNSC is not doing its job by requiring OPG to define meaningful science-based exclusion zones using quantitative criteria and a detailed analysis of potential radiation exposures.

1.5 Defining the Exclusion Zone

CNSC has signed a Memorandum of Understanding (MOU) with NRC to harmonize regulations, and the two agencies are working together on BWRX-300 licensing matters. It is therefore appropriate to expect consistency between the two bodies in the definition of nuclear reactor exclusion zones.

U.S. Nuclear Regulatory Commission (NRC) document 10 CFR 100.11 details how to determine exclusion zones around nuclear power plants. The document is reproduced in Annex B.

According to 10 CFR 100.11, the applicant must begin by assuming a significant fission product release from the core of the reactor. "The fission product release assumed for these calculations should be based upon a major accident . . . that would result in potential hazards not exceeded by those from any accident considered credible. Such accidents have generally been assumed to result in substantial meltdown of the core with subsequent release of appreciable quantities of fission products." See Annex C of this report.

Document 100.11 makes special mention of sites with "multiple reactor facilities" such as Darlington. Again, see Annex B. "If the reactors are interconnected to the extent that an accident in one reactor could affect the safety of operation of any other, the size of the exclusion area . . . shall be based upon the assumption that all interconnected reactors emit their postulated fission product releases simultaneously." The document discusses other factors that might be brought to bear so as to reduce this requirement to some degree. However, any reduction would have to be justified to the satisfaction of the Commission.

Once the fission product release from the core has been established, the applicant must then proceed to calculate how much escapes into the atmosphere by using "the expected demonstrable leak rate from the containment". The meteorological conditions pertinent to the specific site shall then be used to derive an exclusion zone "of such size that an individual located at any position on its boundary would not receive a total radiation dose to the whole body in excess of 25 rem [250 millisieverts] or a total radiation dose in excess of 300 rem [3 sieverts] to the thyroid from [radioactive] iodine exposure."

Recommendations:

7. That OPG be required by CNSC to derive science-based exclusion zones for both Darlington NGS and for the proposed BWRX-300 reactor according to the criteria laid out in U.S. NRC document 100.11.

8. That no new reactor be allowed by CNSC to be built within the exclusion zone of any other existing reactor.

Lest CNSC or OPG staff or any other party mistakenly think that these criteria make it acceptable for ordinary construction workers to work within the exclusion zone of an existing operating reactor, the NRC offers the following clarification:

> "The whole body dose of 25 rem referred to above corresponds numerically to the **once in a lifetime accidental or emergency dose for radiation workers** which, according to NCRP recommendations may be disregarded in the determination of their radiation exposure status (see NBS Handbook 69 dated June 5, 1959). However, neither its use nor that of the 300 rem value for thyroid exposure as set forth in these site criteria guides are intended to imply that these numbers constitute **acceptable limits for emergency doses to the public under accident conditions**. Rather, this 25 rem whole body value and the 300 rem thyroid value have been set forth in these guides as reference values, which can be used in the evaluation of reactor sites with respect to potential reactor accidents of exceedingly low probability of occurrence, and low risk of public exposure to radiation." *[Footnote #2, US NRC 100.11]*

Just to be perfectly clear, NRC states that these calculated doses (25 rem whole body, 300 rem to the thyroid) are **NOT "acceptable limits for emergency doses to the public under accident conditions".** That implies that people who are not radiation workers should not be working in the exclusion zone of an operating nuclear reactor.

The mandate of the CNSC is to protect people against radiation exposure. There is nothing in the mandate of the CNSC having to do with progress. The question is, will CNSC live up to its real mandate? Or will it pursue a fictitious mandate of its own making?

CCNR believes that if CNSC allows OPG to site the BWRX-300 reactor within the exclusion zone of the Darlington Nuclear Generating Station, it will be acting in dereliction of its duty as defined under the Nuclear Safety and Control Act.

1.6 The relevance of the Fukushima accident

The original 2009 EIS and PPE documents were written for a Darlington New Nuclear Project that never came to pass. Those documents were conceived in complete ignorance of the triple meltdown that was about to take place at the Fukushima Daiichi nuclear complex in March 2011. As a result, the two reports do not incorporate any of the lessons learned from the Fukushima disaster – lessons which go far beyond the merely technical.

The reactors that melted down in Japan were Boiling Water Reactors (BWRs) of an early design (circa 1960) supplied by General Electric (GE), Toshiba and Hitachi. They were early precursors of the GE-Hitachi BWRX-300 reactor now under consideration by OPG.

There were six such BWRs co-located at the Fukushima Daiichi site. Unit 1 was rated at 461 megawatts of electrical power (MWe) (half again as large as the BWRX-300) while units 2 to 5 were rated at 780 MWe each. Unit 6 was the largest, rated at 1100 MWe –two and a half times the power of unit 1 and almost 4 times that of BWRX-300.

On March 11, 2011, a powerful 9.1 magnitude earthquake offshore led to the safe shutdown of all these reactors. But within 30 minutes a gigantic tsunami struck, disabling the backup electrical generators and causing a prolonged total station blackout. Without power to run the pumps, there is no way to remove the intense radioactive decay heat from the spent fuel inside the core. In units 1, 2, 3, the fuel began to melt, releasing radioactivity.

Radioactive gases mingled with superheated steam and explosive hydrogen inside the reactor containment vessel. The gases were vented in order to to relieve the pressure that was rapidly building up inside. Once released, the hydrogen gas exploded, punching holes in the outer containment building and spreading radioactive contamination over a vast area. 120,000 people living nearby were evacuated in 2011. Twelve years later, 30,000 of those evacuees are still unable to go home.

An important lesson from Fukushima is that mathematical probability calculations do not protect people from catastrophic events. Before 2011, few in the nuclear industry would have believed that a simultaneous triple meltdown was a credible event. Yet that's what happened. There was a "common cause" for all three meltdowns.

Lessons from Fukushima

1. Simultaneous nuclear disasters can occur at a multi-unit nuclear power plant due to a "common cause" that cannot be predicted accurately ahead of time.

2. For emergency planning one must "expect the unexpected" by postulating a possible radioactive release that may be regarded as having a vanishingly small probability.

Units 1, 2, and 3 are the ones that melted down. Unit 4 was defueled at the time of the disaster, but its outer containment structure (not the reactor containment vessel) was blown apart by one of three violent hydrogen gas explosions. No one knows the exact cause of the unit 4 explosion to this day. The blast blew off the roof of the building and exposed the spent fuel pool to the open air, situated as it was several stories above ground level.

Planes and helicopters were used as water bombers, to douse the spent fuel pool of unit 4. This was done to prevent extensive fuel damage caused by inadequate cooling. If the fuel in the pool had been uncovered by water, overheating could have released far more radioactivity into the atmosphere than had already been released from the 3 reactors that were melting down. Unlike the core which is situated inside a sturdy containment vessel, the pool had no containment at all. Had the uncovered spent fuel become exposed to the open air, a raging zirconium fire could have been ignited amongst the overheated fuel assemblies, leading to unparalleled radioactive releases.

Fukushima has taught us that spent fuel pools are particularly vulnerable to large radioactive releases under certain extreme conditions. Even raging metallic fires are possible when the fuel is not fully covered with water. Even years later, when the risk of overheating has subsided, spent fuel remains intensely radioactive and deadly when dispersed – whether that happens years or decades, or indeed even centuries after removal from the reactor core.

A typical dry storage container for Pickering used fuel weighs 60 tons when empty, and 70 tons when fully loaded. The reason why the dry storage containers designed to hold spent fuel are so much heavier (six times heavier) than the inventory of used nuclear fuel they contain inside, is for one reason only: shielding. Without massive shielding, the penetrating radiation would not be abated and the external risk would be prohibitive

Cooling is another concern. For the last 12 years, hundreds of tonnes of water have been used each day to cool the melted nuclear fuel from the stricken reactors. The water becomes contaminated with fission products flushed out of damaged fuel. Not all radionuclides can be filtered from the water; some, like tritium, can't be removed at all, others remain in residual amounts. More than a million tonnes of radioactive water is currently stored in over 1000 steel tanks.

Despite objections from China, Korea and local fishers, Japan plans to begin dumping that huge inventory of contaminated water into the Pacific Ocean very soon this year. The Pacific Ocean is at least 30,000 times larger in volume than the Great Lakes. It is daunting to think what would happen if such an enormous amount of radioactive water had to be discharged into the Great Lakes basin, the source of drinking water to 40 million people.

Nuclear proponents and supporters say that, on the whole, nuclear power is acceptably safe. But no insurance company in the western world believes that the risk of a nuclear accident is acceptable on actuarial grounds. Every homeowner's insurance policy, without fail, contains a nuclear exclusion clause that voids all coverage in the event of radioactive contamination of property or persons due to a nuclear accident.

1.7 Lessons learned from Fukushima applied to BWRX-300

There are so many lessons to be learned. We now know that co-located reactors may be vulnerable to "common cause" events that can trigger severe core damage in several units at once. It doesn't have to be an earthquake or a tsunami.

It could be a fire that disables all the pumps and electrical controls for example. That nearly happened at the Brown's Ferry nuclear plant in Alabama in 1975. The risk of losing complete control of a nuclear reactor in this way is exacerbated by the continued use of flammable insulating material in nuclear power plant electrical systems – materials that are so flammable they can turn a small fire into a raging inferno.

There is no information in the DNNP documentation about the vulnerability of BWRX-300 to electrical fires. Nor is there any information about the electrical insulation material used in that plant, or about its ability to feed a fire once a fire has started. There is also no information about duplication of wiring systems within the BWRX-300 layout, or the degree of separation between those duplicated wires so that the chances of one fire eliminating all electrical circuits vital for safety by burning up all the wires at once, even the duplicated ones, is minimized.

Fukushima shows us that station blackouts can be especially challenging. Radioactivity cannot be shut off. Therefore effective cooling of spent fuel is essential long after the reactor is shut down.

At Fukushima we also witnessed how much damage hydrogen gas explosions can do. We see how important it is not to underestimate the amount of hydrogen or miscalculate the risk of detonation. A severe nuclear accident always gives rise to hydrogen gas formation in a water-cooled reactor, because hot metals will react with hot steam, stealing the oxygen atoms out of the water molecules and releasing the hydrogen gas into the air.

In Annex C of this report, entitled "Unmet Challenges to Successfully Mitigating Severe Accidents in Multi-Unit CANDU Reactors", Dr. Sunil Nijhawan goes through a litany of examples of how things can go wrong in a multi-unit plant like the Darlington Nuclear Generating Station. Among other things, he discusses the frequent miscalculation of the amount of hydrogen gas buildup in a damaged CANDU reactor core, and the subsequent risk of explosion, which increases the potential radioactive releases from the plant and which serves to increase the area of the exclusion zone – assuming we use the scientific approach laid out by the US Nuclear regulatory Commission, as spelled out in Annex B of this report, instead of the OPG and CNSC practice if simply drawing perfect circles of an arbitrary radius and calling it an exclusion zone.

This entire discussion of CANDU safety would be beside the point and would have no bearing in the siting of the BWRX-300 reactor, were it not for the fact that OPG wants to put the new reactor smack dab inside the exclusion zone of the Darlington multi-unit nuclear power plant.

Of course, when the four CANDU reactors were first built, they were all built within the exclusion zones of each other. However, during the construction period (which began at Darlington in 1981 and finished in 1993) most of the work was done when none of the reactors were operating, The first unit startup was in 1990, so there was less than 3 years of working in the shadow of an operating reactor.

But this was long before the Fukushima experience. We now know better. Fukushima taught us to treat nuclear reactor disasters with respect and not dismiss them as inconsequential because they are unlikely. Knowing what we know now, it would be wrong to allow thousands of workers to labour within the exclusion zones of operating nuclear reactors. Those day are gone.

If the currently chosen site for the BWRX-300 were adopted – and OPG is diligently working on that site right now, even as we speak – the workers would be labouring not only within the exclusion zone of a 3500 megawatt nuclear power complex – one of the largest in North America – but also within a stone's throw of spent fuel in dry storage casks stored in warehouses quite close to the construction site.

The amount of radioactive material inside these spent fuel facilities equals or exceeds the amount inside the cores of the four reactors, because the waste warehouses will accommodate years and years of used fuel bundles that have been accumulating for a long time. A disaster that liberated the radioactive poisons from those containers would constitute a grave threat. Yet OPG and CNSC do not bother to even include them as a "blip" in their risk perception radar, for they do not ascribe any exclusion zone to the spent fuel itself. Only to the reactors.

The lessons of Fukushima are not limited to the physical domain. The breach of trust, the sense of betrayal, can be felt so deeply that it amounts to a rending of the social fabric. In Japan, the greatest sorrow was not related only to the nuclear mishap, enormous as that grief was, but to the fact that people felt they had been lied to by people they trusted. Scientists had repeatedly assured them that nuclear power is safe, safe, safe, and they were stunned and shocked to learn that this was a complete falsehood. A betrayal. How can one learn to trust such people ever again?

What caused the Fukushima nuclear catastrophe? Most people blame the tsunami. The Commission of Investigation in Japan concluded otherwise. In its report to the National Diet, the Commission found that the root cause was a lack of good governance.

The accident "was the result of collusion between the government, the regulators and TEPCO [the nuclear company], and the lack of governance by said parties. They effectively betrayed the nation's right to be safe from nuclear accidents. Therefore, we conclude that the accident was clearly 'man-made.' We believe that the root causes were the organizational and regulatory systems that supported faulty rationales for decisions and actions…" *[Executive Summary of the Commission report to the National Diet of Japan]*

The Commission chairman wrote: "What must be admitted — very painfully — is that this was a disaster 'made in Japan.' Its fundamental causes are to be found in the ingrained conventions of Japanese culture: our reflexive obedience; our reluctance to question authority; our devotion to 'sticking with the program'; our groupism; and our insularity... Nuclear power became an unstoppable force, immune to scrutiny by civil society. Its regulation was entrusted to the same government bureaucracy responsible for its promotion."

Canada has not heeded these warnings. After Justin Trudeau was elected in 2015, his government did away with environmental assessments for any new reactors below a certain size, thus eliminating – or at least sharply limiting – scrutiny by civil society. This leaves all decision-making in the hands of the Canadian Nuclear Safety Commission (CNSC). CNSC was previously identified by an Expert Review Panel (reporting to the Minister of Environment) as an agency that's already widely regarded as a captured regulator.

The CNSC, mandated to protect the public and the environment, reportedly lobbied government to abolish full impact assessments for most "small modular nuclear reactors" (SMNRs). The government of Canada complied. That's why there is no full impact assessment for the BWRX-300 reactor today. And that's why the regulator has cobbled together this charade of allowing OPG to spruce up its PPE and rewrite its EIS of 15 years ago so as to pretend that the public is not being deprived of a genuine opportunity to speak up on behalf of the public interest.

Apparently the Canadian Nuclear Safety Commission feels that it has a more mature appreciation of the public interest than most. In the Globe and Mail, journalist Shawn McCarthy wrote: "The CNSC encourages the government to exempt small modular reactors from the list of designated projects that would receive a full [environmental assessment] panel review, and warns that lengthy regulatory delays could kill a promising industry" Who knew that an "independent regulator" would be so dedicated to the well-being of the industry it is mandated to regulate? Who knew that regulatory delays would be so galling to the regulator? Could it be because CNSC receives most of its operating budget from the licensees? Or has the CNSC adopted a higher purpose, more appealing than the one parliament deigned to give to it?

During the 17 days of Environmental Assessment hearings, held from March 21 to April 8, 2011, many intervenors raised the Fukushima accident in their testimony to the Joint Review Panel. In their EA Report, the JRP mentioned the Fukushima accident 19 times. Here are some examples:

"Participants explained that they felt that the OPG safety analysis was probabilistic and not deterministic or realistic enough. They felt that worst-case beyond design basis accidents were not fully considered, despite the fact that nuclear accidents can and do happen, such as at Three-Mile Island (1979), Chernobyl (1986) and Fukushima Daiichi (2011). Participants noted that accidents could be caused by a combination of factors, including human error, severe weather, equipment failure and improper design. Participants felt that even if the probability of an accident is low, the consequences would be unacceptable should one occur."

"The Panel … notes that the Long-Term Energy Plan and Supply Mix Directive were developed before the Fukushima Daiichi nuclear accident. Since this accident, more concerns have been raised about nuclear power generation globally…. The Panel wishes to acknowledge the desire expressed by many participants for a re-examination of the Ontario energy alignment."

The people of Ontario, indeed the people of Canada and the world, deserve to have an independent and thorough Environmental Assessment of this new, untested reactor, the BWRX-300, especially as it is intended to be built within the exclusion zone of a very large nuclear power complex, not far from major rail line and highway linking Toronto to Montreal, and within a relatively short distance (as the crow flies) from one of Canada's largest cities and most important manufacturing centres.

The Canadian Coalition for Nuclear Responsibility is confident that an independent environmental impact review would conclude that the proposed siting of this proposed reactor is quite simply wrong.