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Our File: 2021-02-01

VIA ELECTRONIC MAIL

August 25, 2021

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RE: REQUEST TO REFER THE ENVIRONMENTAL ASSESSMENT OF THE PROPOSED WEST COAST OLEFINS LTD. ETHYLENE PROJECT IN PRINCE GEORGE AND ASSOCIATED PROJECTS TO AN INDEPENDENT PANEL OF EXPERTS TO CONDUCT A REGIONAL ASSESSMENT BY WAY OF PUBLIC HEARINGS

On behalf of Too Close 2 Home, we request that the Minister refer the current environmental assessment of the proposed West Coast Olefins Ltd. (WCOL) Ethylene Project to an independent panel of experts to conduct the assessment by way of public hearings, pursuant to s. 14 of the *Environmental Assessment Act*, SBC 2002.[2]

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[1] We write to Elenore Arend in her capacity as Chief Executive Assessment Officer under the *Environmental Assessment Act,* SBC 2018 and also in her capacity as "Executive Director" of the Environmental Assessment Office under the former *Environmental Assessment Act,* SBC 2002. See footnote below.

[2] Note that because of timing of the consideration of the Ethylene Project, the Environmental Assessment Office has determined that the assessment of the Ethylene Project in question will be conducted pursuant to the former *Environmental Assessment Act*, SBC 2002, c 43, instead of the 2018 Act. (See *Letter confirming that the EA will continue under Environmental Assessment Act, 2002,* at: <https://projects.eao.gov.bc.ca/api/public/document/5ef112136ff33f002173d6dd/download/358416_Ron%20Just_Final%20for%20EPIC.pdf>.
Section 14 of the 2002 statute provides:
"14 (1) If the executive director under section 10 (1) (a) refers a reviewable project to the minister, the minister by order
(a) may determine the scope of the required assessment of the reviewable project, and
(b) may determine procedures and methods for conducting the assessment, including for conducting as part of the assessment a review, under section 16 (6), of the proponent's application.
(2) The minister's discretion under this section to determine scope, procedures and methods includes but is not limited to the discretion by order to exercise any of the powers in section 11 (2).

In addition, pursuant to s. 35 of the *Environmental Assessment Act,* SBC 2018,[3] we request that the Minister direct the same panel to conduct a simultaneous Regional Assessment of the impacts of the Ethylene Project – in the context of additional impacts caused by the directly linked proposed:

- Upstream Natural Gas Liquid Recovery Project, which will create fossil fuel products; and
- Downstream Polyethylene Plant, which will create plastic pellets.[4]

The Ethylene Project currently being assessed is just one of three intimately connected projects that rely upon a common source of natural gas input and share by-products of the others. A comprehensive assessment of cumulative impacts of all three projects is required.

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(3) **An order of the minister making a determination under this section may**
(a) require that the assessment be conducted
(i) by a commission that the minister may constitute for the purpose of the assessment, consisting of one or more persons that the minister may appoint to the commission,
(ii) **by a hearing panel, with a public hearing to be held by one or more persons that the minister may appoint to the hearing panel…**
(b) delegate any of the minister's powers under this section to make orders determining scope, procedures and methods to…
(ii) a commission member, hearing panel member or another person, depending on which of them is responsible for conducting the assessment.
(4) For the purposes of an assessment conducted under this section by a commission or hearing panel, the minister by order may confer on the commission or hearing panel, as the case may be, the powers, privileges and protection given under sections 12, 15 and 16 of the *Inquiry Act* to a commissioner appointed under Part 2 of that Act."
In the alternative, if it is determined that the *Environmental Assessment Act*, SBC 2018, c 51 should apply to this matter, section 24 of the latter Act authorizes the Minister to do the same thing. Section 24 authorizes the Minister to order the assessment be conducted by "a hearing panel, with a public hearing to be held by one or more individuals that the minister may appoint to the hearing panel…"; and empowers the Minister to delegate to the panel the power to set scope, procedures and methods of the assessment, and to exercise the powers of a commission of public inquiry.

[3] The 2018 statute applies here, because the requested s. 35 action is not grandfathered by previous assessment process. Section 35 of the 2018 statute provides for assessments of a number of projects in a region. Section 35 provides:
"35(1) **The minister may direct the chief executive assessment officer or an assessment body to do the following**, in accordance with terms of reference established by the minister and with regulations made under subsection (3):
(a) **undertake an assessment of the environmental, economic, social, cultural and health effects of any projects in a region of the province;**
(b**) provide a report and recommendations to the minister at the conclusion of the assessment.**.

[4] Winston Szeto, "Prince George, BC, once again considered as potential home for plastics plant," *CBC News* (2020 December 20) online: <https://www.cbc.ca/news/canada/british-columbia/prince-george-west-coast-olefins-petrochemical-facility-back-1.5848175>.

THE THREE PROJECTS MUST BE ASSESSED TOGETHER

West Coast Olefins Ltd. has described the intimate relationship between all three projects.[5] Indeed, the interconnection of all three projects is reflected in the Company's own flow charts:

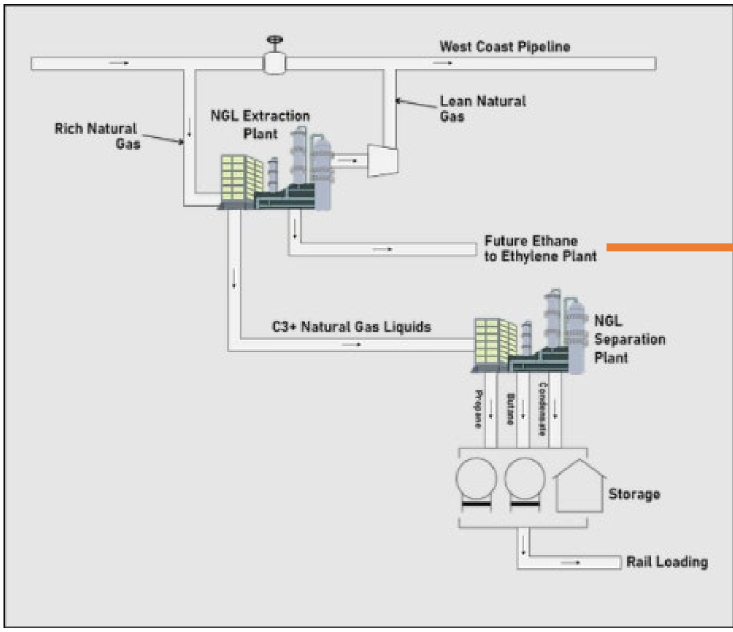

Figure 1: Proposed NGL Recovery Project[6]

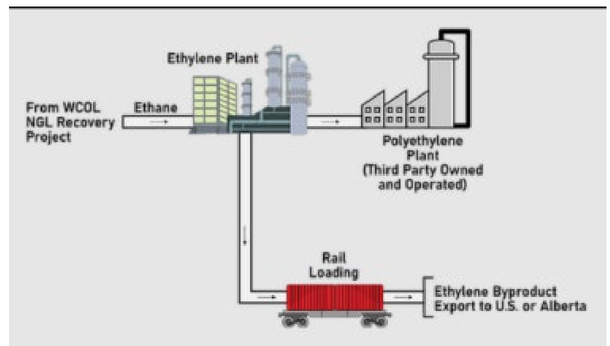

Figure 2: Proposed Ethylene Project and Polyethylene Plant[7]

[Orange arrow has been added for clarity.]

In a very real sense, all three proposed projects form an interconnected, multi-billion dollar petrochemical industrial complex. Indeed, WCOL has apparently described these three projects as one 'overall project' to local media:

> *According to WCO, the overall project will include a natural gas liquids recovery plant to recover ethane, propane, butane, and natural gas condensate from Enbridge's West Coast Pipeline; an ethylene plant to produce one million tonnes per year of polymer-grade ethylene; a polyethylene plant to consume most of the ethylene produced; and associated off-site facilities and infrastructure.*[8]

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[5] Winston Szeto, "Prince George, BC, once again considered as potential home for plastics plant," *CBC News* (2020 December 20) online: <https://www.cbc.ca/news/canada/british-columbia/prince-george-west-coast-olefins-petrochemical-facility-back-1.5848175> and Mark Neilson, "Petrochemical complex to head back to city," *Prince George Citizen* (2020 December 16) online: < https://www.princegeorgecitizen.com/local-news/petrochemical-complex-to-head-back-to-city-3742233>.

[6] West Coast Olefins Ltd., "Prince George NGL Recovery Project," West Coast Olefins Ltd Projects, online: <https://www.westcoastolefins.com/pg-ngl-recovery-plant>. Note that the orange arrow has been added for clarity.

[7] West Coast Olefins Ltd., "Prince George Ethylene Project," West Coast Olefins Ltd Projects, online: <https://www.westcoastolefins.com/pg-ethylene-plant>. Note that the orange arrow has been added for clarity.

[8] Canadian Plastics, "New Canadian company wants to build $5.6 billion petrochemical plant in B.C.," *Canadian Plastics* (2019 July 31) online: <https://www.canplastics.com/canplastics/west-coast-olefins-seeks-to-build-5-6-billion-petrochemical-plant-in-b-c/1003450462/>.

The link between the three projects couldn't be clearer. For example, WCOL's CEO, Ken James, has stated baldly:

> *You can't have the Ethylene Plant without the NGL Recovery Plant…* [9]

Indeed, the CEO has called the overall petrochemical complex "the biggest project the city has ever seen."[10] This "overall project" will have profound effects on the City of Prince George and the entire region. As discussed below, the overall petrochemical complex raises existential questions about the type of community that Prince George will be in the 21st century. The complex poses significant hazards to the local environment and public health in the Prince George region. It also poses profound economic risk to the Province – an investment in fossil fuel infrastructure is likely to become worthless because climate change is forcing the rapid phase-out of fossil fuels.

Perhaps most important, the petrochemical/plastic complex poses profound risks to the global environment because it may:

- Make it impossible to ever address the global climate emergency that set BC on fire this summer (A *Scientific American article* – "Plastic Plants Poised to be the Next Big Carbon Superpolluters" – asserts that the new boom in complexes such as this "*could lock in greenhouse emissions for decades to come"*[11]*)*;
- Spur fracking and other harmful natural gas production activities;
- Spur widespread plastic pollution that does major environmental harm;
- Undermine provincial and federal efforts to reduce plastic waste; and
- Undermine government efforts to encourage plastic recycling.

Yet the $2.8 billion Ethylene Project is the only one of the three projects now being assessed under the *Environmental Assessment Act.*[12] The problem is that this one project under assessment is only a small part of a much bigger picture – only one part of the massive petrochemical complex planned.

In 2019, WCOL stated it was negotiating with potential "third party partners," who would use their products to produce the polyethylene plastic pellets. See: Ken James, "*Response from West Coast Olefins"* (Statement of the CEO of the Project Proponent) (2019 September 11) online: <https://www.princegeorgecitizen.com/opinion/response-from-west-coast-olefins-3737817>. WCOL has stated that it hopes to see the polyethylene plastic pellet facility up and running by 2024. See: Mark Neilson, "Petrochemical complex to head back to city," *Prince George Citizen* (2020 December 16) online: <https://www.princegeorgecitizen.com/local-news/petrochemical-complex-to-head-back-to-city-3742233>.

[9] BC Resources Coalition, "The BCRC Show Episode 21: CEO of the West Coast Olefins Ken James, President of BCRC Willy Manson" (2020 December 19) at 41m: 48s, online (video): *YouTube* <https://www.youtube.com/watch?v=B9WW2GLqJC8&t=2508s>.

[10] Quote taken from event in Prince George where Ken James, CEO and president of WCOL, was introducing the petrochemical complex and all its constituent parts. See: Hanna Petersen, "'It's a game changer:' Calgary company plans to build $5.6B petrochemical plant in Prince George*" Prince George* Citizen (2019 July 24), online: <https://www.princegeorgecitizen.com/local-news/calgary-company-to-build-56b-petrochemical-plant-in-prince-george-1602606>.

[11] Benjamin Storrow, "Plastic Plants are Poised to Be the Next Big Carbon Superpolluters" *Scientific American* (2020 January 24), online: <https://www.scientificamerican.com/article/plastics-plants-are-poised-to-be-the-next-big-carbon-superpolluters>. See the detailed discussion of all these bulleted points, below.

[12] The Ethylene Project has been granted a Section 11 Order under the *Environmental Assessment Act,* SBC 2002 on December 10, 2019. See: British Columbia Environmental Assessment Office Project Information Center, *"IN THE MATTER OF THE ENVIRONMENTAL ASSESSMENT ACT S.B.C. 2002, c.43 (ACT) AND AN ENVIRONMENTAL ASSESSMENT OF THE WEST COAST OLEFINS ETHYLENE PROJECT (PROPOSED PROJECT) ORDER UNDER SECTION 11"* (Order), online:

The second facility – which will refine natural gas into other fuels[13] and feed the Ethylene Project – is the massive $1.3 billion Natural Gas Liquids Recovery Project. However, unless the Minister accedes to our request, that project may not be subject to a formal environmental assessment under the *Environmental Assessment Act*. Indeed, WCOL has boasted that it has "actually split… out" this latter plant to be considered by a simpler, more rudimentary Oil and Gas Commission permitting process.[14] Currently, WCOL does not contemplate a formal environmental assessment proceeding under the *Environmental Assessment Act*.[15]

As for the third facility, WCOL has acknowledged that the $1.5 billion polyethylene plant producing polyethylene pellets for plastics production is also part of the "overall project." Yet, because WCOL claims that a third party will propose that part of the overall project *later on*, no environmental assessment is likely to take place for this third project until much later – likely *after approvals* of the other parts of the complex have already been obtained.

Yet a future assessment of the third facility is likely to be powerfully skewed if billions of dollars have already been spent – and numerous jobs created – implementing the other two approved components of the "overall project." The investments and jobs established for the first two facilities may impel approval of the final part of the petrochemical complex. The pressure to complete an "overall project" that is halfway there will be substantial. Economic theory teaches that the "Sunk Costs Fallacy" will come into play and prevent objective assessment of that final project:

> *The sunk cost fallacy means that we are making decisions that are irrational and lead to suboptimal outcomes. We are focused on our past investments instead of our present and future costs and benefits, meaning that we commit ourselves to decisions that are no longer in our best interests.*[16]

<https://projects.eao.gov.bc.ca/api/public/document/5df0143ef7f30e0021e731b0/download/West%20Coast%20Olefins%20Ethylene%20Section%2011%20Order.pdf>.

[13] According to WCOL, rich natural gas from the West Coast Pipeline will be refined into lean natural gas, propane, and butane, which are all fossil fuels which will be shipped via pipeline and rail for end use elsewhere. See: West Coast Olefins Ltd., "Prince George NGL Recovery Project," West Coast Olefins Ltd Projects, online: <https://www.westcoastolefins.com/pg-ngl-recovery-plant>.

[14] See the statement by CEO and president of WCOL, Ken James: "…The OGC process is actually a little simpler so we get through that regulatory process a little faster so it makes a lot of sense that we can actually split the projects out and have one lead by 6 months to a year." See: BC Resources Coalition, "The BCRC Show Episode 21: CEO of the West Coast Olefins Ken James, President of BCRC Willy Manson" (2020 December 19) at 43m: 03s, online (video): *YouTube* <https://www.youtube.com/watch?v=B9WW2GLqJC8&t=2583s>.

[15] In a letter to residents WCOL states "WCOL will have to gain regulatory approvals from the Oil and Gas Commission, the Agricultural Land Commission and the Regional District for rezoning. As well, WCOL will work with NavCanada to ensure that the towers and flare stack are registered." No mention is made of an environmental assessment under the *Environmental Assessment Act*. See: West Coast Olefins Ltd. August 3, 2021 letter from Christine Olson addressed To Whom it May Concern, "Re: West Coast Olefins Proposed NGL Extraction Plant 25 acres parcel in the NW corner of West ½ District Lot 1946 PID 006-284-582".

[16] The Decision Lab, "Why are we likely to continue with an investment even if it would be rational to give it up?" online: <https://thedecisionlab.com/biases/the-sunk-cost-fallacy/>.

[The Sunk Costs Fallacy is also known as the "Concorde Fallacy." The UK and French governments experienced massive financial loss because they "took their expenses on the costly supersonic jet as a rationale for continuing the project, as opposed to 'cutting their losses.'"[17]]

The fundamental point is that there needs to be a timely independent expert assessment of the overall project now. The assessment of the largest industrial development in Prince George history needs to assess all three part of the development at the same time. If government only assesses one part of the development now, it will miss the big picture, and the overall impacts of the development.

Proceeding with just an assessment of the Ethylene Project risks missing essential information. Looking at just part of the whole will likely lead to error. It runs the risk faced by the three ancient people who ran into an elephant in the dark:

> *The person who felt the ear said it was a **fan**. The person who felt the elephant's side said that it was a **wall.** The person who felt the elephant's trunk said that it was a **snake**.*

The moral of the story is that you have to see the entire thing – the whole petrochemical complex – to come to any kind of rational conclusion. British Columbians must have an assessment of the overall project, to see what real-world, cumulative impacts are likely. It is not enough to just examine the Ethylene Project – that's just the elephant's trunk.

Taken altogether, a truly massive, multi-billion dollar petrochemical industrial complex is being proposed – with the Ethylene Project being just phase one of a development that could transform Prince George, harm the regional environment, and seriously compromise Planet Earth by exacerbating climate change and global plastic pollution. The public needs an accurate and complete picture of what is in the offing. Only a comprehensive examination of all three projects, by way of a regional assessment, can provide that.

The "overall project" should not proceed without the most careful environmental assessment of what is ultimately being proposed, and potential local, regional and global impacts. It is essential to determine whether the proposed Ethylene Project – and the linked Natural Gas Liquid Recovery Project and Polyethylene Plant – are consistent with *Government's stated objectives* to:

- Fight climate change;
- Reduce unnecessary plastic waste; and
- Enhance recycling and create a circular economy.

Below we document evidence that the proposed petrochemical complex will, in fact, seriously undermine all these stated government objectives. An independent expert review is needed to determine whether this is so. In addition, the panel is needed to consider other potentially serious impacts on Indigenous peoples, local citizens, and the region's environment. The panel must also determine the risk that the complex could foreclose a more prosperous and sustainable future for Prince

[17] Wikipedia, "Sunk Costs," online: <https://en.wikipedia.org/wiki/Sunk_cost>.

George. Finally, the expert panel must analyze whether this fossil fuel infrastructure is likely to become "worthless" to BC in the long term – as Mark Carney and other eminent experts warn.[18]

Note that section 14 of the *Environmental Assessment Act, 2002*[19] authorizes the Minister to appoint an independent expert panel to conduct an environmental assessment and public hearings on the matter. Due to the importance of the issues involved, such a process is clearly necessary for the Ethylene Project that is currently being assessed.

In addition, section 35 of the *Environmental Assessment Act,* 2018 empowers the Minister to direct the assessment body to undertake an assessment of the environmental, economic, social, cultural, and health effects of ***any* projects in a region of the province,** in the form of a regional assessment. A regional assessment is needed here to capture the broader and cumulative impacts of the entire petrochemical complex – including the Ethylene Project, the upstream Natural Gas Liquid Recovery Plant, and the downstream Polyethylene Plant.

The entire petrochemical complex raises issues of immense environmental, health and social importance. The potential profound impacts upon Prince George, the province, Canada, and the planet require careful and comprehensive investigation and scrutiny.

THE PERTINENT FACTS

In considering whether to refer this matter to an independent expert panel for public hearings and direct that the matter be considered in the form of a regional assessment, we urge you to consider the following facts:

First Nations Opposition to the Proposed Petrochemical Complex

Note that the Lheidli T'enneh Nation and McLeod Lake Indian Band have publicly opposed the proposed WCOL petrochemical complex. On December 16, 2020, the two First Nations stated that they oppose WCOL advancing the project on the proposed BC Rail industrial site and that there will be no future negotiations between the parties.[20] The Lheidli T'enneh Nation has unequivocally stated their position about the proposed Ethylene Project and NGL Recovery Project on their unceded territory:

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[18] See the discussion of stranded assets below.

[19] Because of the timing of the initial consideration of the Ethylene Project, the Environmental Assessment Office has determined that the assessment of the Ethylene Project in question will be conducted pursuant to the former *Environmental Assessment Act*, SBC 2002, c 43, instead of the 2018 Act. (See *Letter confirming that the EA will continue under Environmental Assessment Act, 2002,* at: <https://projects.eao.gov.bc.ca/api/public/document/5ef112136ff33f002173d6dd/download/358416_Ron%20Just_Final%20for%20EPIC.pdf>.

[20] Prince George Citizen Staff, "First Nations Oppose Petrochemical Complex," *Prince George Citizen* (2020 December 17) online: <https://www.princegeorgecitizen.com/local-news/first-nations-oppose-petrochemical-complex-3742242> and Jeff Balzer "First Nation bands say there 'will be no future negotiations' in Prince George relocation proposal for West Coast Olefins plant," *The Prince George Citizen* (2020 December 17), online: <https://www.princegeorgecitizen.com/local-news/first-nation-bands-say-there-will-be-no-future-negotiations-in-prince-george-relocation-proposal-for-west-coast-olefins-plant-3193798>.

> *WCOL is not welcome in LTFN territory and on unceded ancestral lands.*[21]

That should be the end of the matter. In any case, in light of this First Nations opposition, there is no way that a routine assessment and approval can go forward. Indeed, First Nations must be fully involved in all decision making going forward.

Citizen Opposition to the Petrochemical Complex

Note that there is also widespread concern in the community about the proposed project. There is substantial citizen opposition. For example, Too Close 2 Home is a community group concerned about the proposed petrochemical complex. The group has a Facebook page with about 800 members, who are concerned about the project proposal. The group has held several public/open events. There is also now significant citizen opposition to the proposed Pineview site as well, represented in the Grasslands Not Gaslands Facebook page, with over 130 members. A recent petition calling for an assessment by independent experts conducting public hearings has been signed by hundreds of people; and a second related petition now has over 1,100 signatures and climbing.[22] Public concern has risen to a level that justifies a review of the issues by independent experts.

THE PETROCHEMICAL COMPLEX'S IMPLICATIONS FOR THE PRINCE GEORGE AREA

Air quality

This project could undermine air quality – in a city where air quality is a major public concern. The Prince George air shed is already burdened with considerable industrial, transportation, residential and wildfire pollution. Indeed, in 2018 wildfires gave Prince George some of the worst air pollution levels in the world.[23] In addition, the City of Prince George has had a long history of serious industrial air pollution problems, exacerbated by the strong inversion effects that trap pollutants in the City.[24] It has been estimated that as many as 81 deaths per year in Prince George may be attributable to air pollution.[25]

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[21] Lheidli T'enneh First Nation, "West Coast Olefins Ltd. Not Welcome in LTFN Territory," (2021 August 4) (News Release), online: <https://www.lheidli.ca/west-coast-olefins-ltd-not-welcome-in-ltfn-territory/>.

[22] Stop Pineview Plastics Plant, "Stop the plastics plant in Pineview," Change.org, online: <https://www.change.org/p/regional-district-of-fraser-fort-george-directors-stop-the-plastics-plant-in-pineview>.

[23] Joti Grewal, "Prince George among cities with worst air quality worldwide in 2018: report" *The Interior News* (2019 March 5) online: <https://www.interior-news.com/news/prince-george-among-cities-with-worst-air-quality-worldwide-in-2018-report/>.

[24] Note that air modelling shows that dominant air patterns would tend to push much of the pollution created by the complex, along the River to College Heights and towards downtown Prince George, two areas that are within 3 and 5 kilometres of the Ethylene Project. Frequent inversions tend to hold poor air in the bowl of Prince George, which has the City's largest population concentration.

[25] See *Times Colonist*, "Pollution Proves Deadly in Prince George: Study", December 22 2007 and Elliott, Catherine and Copes, Ray, *Burden of Mortality due to Fine Particulate Air Pollution (PM2.5) in Interior and Northern B.C.*, Can J Public Health 2011; 102(5): 390-39, p. 391 ("Elliott and Copes 2011").

The incidence of asthma and chronic lung disease have long raised local health concerns.[26] Consequently, air quality has been a priority issue in Prince George in recent years.

Indeed, a Regional District document has stated:

> *The city of Prince George's air shed has been identified as not being able to accept additional air emissions without compromising the health of its citizens...The Regional Board supports the elimination of health hazards and minimization of air and water pollution.*[27]

In light of current air quality concerns, the proposed project must be carefully assessed – because petrochemical plants have been associated with high rates of cancer and other disease. "Petrochemical production can release airborne toxins such as 1,3-Butadiene, benzene, and toluene, causing cancer and other illnesses."[28]

A 2019 corporate report noted that over 30,000 kg of fugitive volatile organic compounds were released from a similar Nova facility in Red Deer, Alberta. That plant also releases ethylene and NO_2 pollutants.[29] The public in St. James, Louisiana has vociferously opposed a proposed plastics manufacturing plant for health reasons. "St. James is in the heart of Cancer Alley — an 85-mile stretch along the Mississippi River with a high concentration of industrial plants, and high cancer rates among residents."[30] The Canadian Association of Physicians for the Environment (CAPE) has launched a campaign called "Unnatural Gas" to draw attention to the negative health impacts of the natural gas industry due to the many pollutants

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[26] "Concerns about respiratory impacts such as asthma and chronic lung disease caused by Prince George's already poor air quality has long been a pressing topic for health advocates. High rates of cancer, recurrent sinus and middle ear infections, cardio-vascular, and cerebro-vascular disease are also major problems being dealt with by medical practitioners within Prince George." See: Eriel Strauch, "Social and medical concerns for Prince George heightened by West Coast Olefins proposed plants" *Canada-Info.ca* (2021 March 12), online: <https://canada-info.ca/en/social-and-medical-concerns-for-prince-george-heightened-by-west-coast-olefins-proposed-plants/>.

[27] Regional District of Fraser-Fort George, "Prince George Area Industrial Land Profile," Regional District of Fraser-Fort George – Documents and Resources, (2008 May) at p. 8, online (pdf): <https://rdffg.bc.ca/uploads/745/PGArea_Industrial_Lands_Profile.pdf>.

[28] Beth Gardiner, "The Plastics Pipeline: A Surge of New Production Is on the Way," Yale Environment 360, (2019 December 19) online: <https://e360.yale.edu/features/the-plastics-pipeline-a-surge-of-new-production-is-on-the-way>.

[29] See Nova Chemicals report on its emissions at their Joffre Site in : Nova Chemicals, "SiteLine – Joffre Site Community News" (2020) 31:2, online (pdf): <https://www.novachem.com/download?id=3750>; For more detail, see the Canadian National Pollutant Release Inventory's data: <https://pollution-waste.canada.ca/national-release-inventory/archives/index.cfm?do=facility_substance_summary&lang=en&opt_npri_id=0000001779&opt_report_year=2017&fbclid=IwAR0fA1WsT1mjR4ruTTQtuF8u6OugKP02A5zS7tG1wQt8t2RgthakLTeeGQg#cac>.

[30] See this Note/Commentary about an area in Southern Louisiana known as 'Petrochemical America: Courtney J. Keehan, "Lessons from Cancer Alley: How the (US) Clear Air Act has failed to protect public health in Southern Louisiana" (2018) 29:2 Colo. Nat. Resources, Energy & Envtl. L. Rev. 341, online (pdf): <https://www.colorado.edu/law/sites/default/files/attached-files/keehan_online_copy.pdf>; and Earthjustice, "How Big Oil is Using Toxic Chemicals as a Lifeline – and How We Can Stop It" (2020 July 2) online: <https://earthjustice.org/features/petrochemicals-explainer>.
For more on the petrochemical industry and cancer, see: V. Iyer, and N. Mastorakis, *Unsafe Petrochemical Refinery Air Pollution And Its Environmental Impact Assessment* (Canary Islands: World Scientific and Engineering Academy and Society, 2009) online: <https://hero.epa.gov/hero/index.cfm/reference/details/reference_id/2205466>. Also, see: Elaine MacDonald & Sarah Rang, *Exposing Canada's Chemical Valley: An Investigation of Cumulative Air Pollution Emissions in Sarnia, Ontario Area* (Report) (Toronto: Ecojustice, 2007), online: <https://ecojustice.ca/wp-content/uploads/2015/09/2007-Exposing-Canadas-Chemial-Valley.pdf>.

released through the extraction, transmission, and use.[31] Clearly there must be a thorough assessment of the chemicals that would be emitted by the proposed Prince George facilities.

There must also be an examination of particulate air pollution. Prince George already has challenges managing its $PM_{2.5}$ concentrations, with contributions from industry, transportation, wood stoves, and forest fires. Any additional $PM_{2.5}$ production associated with the new complex would be a concern,[32] especially given that the BCR Industrial Site, where the complex is proposed, exceeded the air quality objectives for $PM_{2.5}$ in 2014-2016.[33] Industrial sources in Prince George were the largest source of $PM_{2.5}$ in 2014-2016.[34] Despite WCOL's CEO asserting that the NGL Recovery Project and Ethylene Project will not create any particulate pollution because they "do not have solid products,"[35] the impacts of potential particulate pollution needs careful assessment. For example, an assessment should look at PM2.5 production from the polyethylene plant – and at whether all the projects may exacerbate PM2.5 pollution in other ways, e.g., during construction and during use (e.g. employee travel to and from work, trucking construction materials, and trucking required for routine operations).

In sum, the potential impact of the entire petrochemical complex upon air quality must be given the most careful consideration – it must be assessed by a panel of independent experts holding public hearings.

Worker and residential health impacts generally

The project raises important occupational health concerns as well. Impacts of particular concern fall into three classes: carcinogenic, mutagenic, and endocrine disruptor-related impacts. An extensive list of potential occupational diseases associated with such facilities is found in the scientific literature footnoted below.[36]

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[31] Canadian Association of Physicians for the Environment & Canadian Association of Nurses for the Environment, "How Healthy is Natural Gas?," online: <https://www.unnaturalgas.org/?utm_source=coast%20reporter&utm_campaign=coast%20reporter&utm_medium=referral>.

[32] Catherine T Elliott & Ray Copes, "Burden of Mortality due to Ambient Fine Particulate Air Pollution (PM 2.5) in Interior and Northern BC"(2011) 102(5): 390-393 Canadian Journal of Public Health, online (pdf): https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6973564/pdf/41997_2011_Article_BF03404182.pdf. .

[33] Brayden Nilson, Peter Jackson, Bruce Ainslie, & Gail Roth, "Prince George Air Quality Emissions and Modelling (2014-2016)" (Presentation for Prince George City Council Meeting) (2021) at slide 9, online: <https://pub-princegeorge.escribemeetings.com/filestream.ashx?DocumentId=7045&utm_source=prince%20george%20citizen&utm_campaign=prince%20george%20citizen&utm_medium=referral>.

[34] Brayden Nilson, Peter Jackson, Bruce Ainslie, & Gail Roth, "Prince George Air Quality Emissions and Modelling (2014-2016)" (Presentation for Prince George City Council Meeting) (2021) at slide 5, online: <https://pub-princegeorge.escribemeetings.com/filestream.ashx?DocumentId=7045&utm_source=prince%20george%20citizen&utm_campaign=prince%20george%20citizen&utm_medium=referral>.

[35] Ken James, "*Response from West Coast Olefins"* (Statement of the CEO of the Project Proponent) (2019 September 11) online: <https://www.princegeorgecitizen.com/opinion/response-from-west-coast-olefins-3737817>.

[36] Robert DeMatteo, *Chemical Exposure and Plastics Production: Issues for Women's Health – a Review of* Literature (Prepared for National Network on Environments and Women's Health, 2011 December), online (pdf): <http://cwhn.ca/sites/default/files/resources/cancer/short%20lit%20review-%20EN%20-%20formatted.pdf>. Also see: Courtney J. Keehan, "Lessons from Cancer Alley: How the (US) Clear Air Act has failed to protect public health in Southern Louisiana" (2018) 29:2 Colo. Nat. Resources, Energy & Envtl. L. Rev. 341, online (pdf): <https://www.colorado.edu/law/sites/default/files/attached-files/keehan_online_copy.pdf>

For example, there are specific concerns about health impacts on women workers. Chemical exposures of women workers in the plastics industry have resulted in dramatically higher rates of breast cancer.[37]

The issues of both workers’ and residents’ health and safety must be comprehensively addressed by independent experts.

Fire and Explosion Risks

Fires and explosions are a risk at most petrochemical facilities.[38] A comprehensive assessment needs to analyze the risks of fire, explosion, and consequent serious pollution that may occur at petrochemical facilities such as those proposed. As the Inland Marine Underwriters Association has pointed out:

> *Flammable organic solvents are found in nearly every plastic plant [including ethylene plants]. Solvents typically are highly volatile, represent a serious fire hazard…Improper handling of flammable liquids has caused serious fires in plastics plants.*

A 2019 Yale University environmental journal article gave an example of the problem:

> *The day before Thanksgiving, a blaze at the Texas Petroleum Chemical plant in Port Neches set off two explosions, forcing 50,000 people to evacuate their homes. A week later, authorities issued another evacuation warning after air monitors detected high levels of carcinogenic 1,3 Butadiene.*[39]

In fact, the Solex Gas Liquids plant, located in Taylor, BC, experienced a series of explosions in 2000, injuring 14 employees at the plant and leading to the evacuation of 1,200 residents.[40] Like the proposed NGL Extraction Project, the Solex plant recovered propane, butane, and ethane from natural gas.[41]

Similarly, a fire at a plastics plant near Chicago created hazardous fumes that forced evacuation of nearby residents.[42] An explosion at a plastics factory in Edmonton sent nine people to hospital,[43] and an

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[37] “If we looked at women under the age of 50, pre-menopausal women, these women’s risk …took off like a rocket. They were over 400 per cent increased risk” said James Brophy, lead author of a study about exposure to plastic fumes and related breast cancer risk. Quote from: Gil Shochat & Megan Rowney, “Exposed to plastic fumes, women working in some factories have a 400% increased risk of breast cancer, study says,” *Global News* (2014 January 24), online: <https://globalnews.ca/news/1099930/experts-push-for-increased-protections-for-women-exposed-to-plastics-fumes/>. See study cited: James T Brophy, et al. “Breast cancer risk in relation to occupations with exposure to carcinogens and endocrine disruptors: a Canadian case–control study” (2012) 11:87 Environmental Health, doi: 10.1186/1476-069X-11-87, online (pdf): <https://ehjournal.biomedcentral.com/track/pdf/10.1186/1476-069X-11-87.pdf>.

[38] Merrit Kennedy, “Massive Explosion Rips Through Texas Chemical Plant, National Public Radio,” NPR (2019 November 27), online: <https://www.npr.org/2019/11/27/783263942/massive-explosion-rips-through-texas-chemical-plant>.

[39] Beth Gardiner, “The Plastics Pipeline: A Surge of New Production Is on the Way,” Yale Environment 360, (2019 December 19), online: <https://e360.yale.edu/features/the-plastics-pipeline-a-surge-of-new-production-is-on-the-way>.

[40] CBC News, “Taylor BC evacuated after explosion,” (Last updated: 2000 November 10), online: <https://www.cbc.ca/news/canada/taylor-b-c-evacuated-after-explosion-1.188068>

[41] Government of British Columbia, “POWER FOR JOBS HELPS SOLEX EXPAND TAYLOR PLANT,” (News Release) (2000 July 28), online: <https://archive.news.gov.bc.ca/releases/archive/pre2001/2000/nrs2000/034nr.asp>.

[42] CBS News Chicago, “Fire at Plastics Plant Creates Hazardous Fumes in Zion,” (2012, June 17), online: <https://chicago.cbslocal.com/2012/06/17/fire-at-plastics-plant-creates-hazardous-fumes-in-zion/>.

[43] Amanda Ferguson, “Plastics Factory Blast Leaves Community Shaken,” *CTV News* (2008 October 24), online: <https://edmonton.ctvnews.ca/plastics-factory-blast-leaves-community-shaken-1.336753>.

explosion at a Chinese polyethylene plant killed seven.[44] Such explosions can create pollution that threatens the environment and the health of residents.[45]

Residents of the Prince George area vividly remember the 2018 Westcoast gas pipeline explosion just north of the City, which forced the evacuation of 100 people from the Lheidli T'enneh First Nation.[46] Members of the Nation have remarked that they were worried about another explosion – and that witnessing the explosion was "traumatic."[47]

The risks of fire and explosion – including hazards to the environment and citizen safety – need to be thoroughly investigated by independent experts. The fire and explosion risk is especially of concern in light of the proximity of the projects to residents.

Impacts on Water and Fish

The Project is located in a watershed of local, provincial, and global importance. For example, a stream immediately adjacent to the Ethylene Project site feeds into the Fraser River, a Canadian Heritage River that supports some of the world's greatest salmon runs.[48] Chinook salmon, rainbow trout and other freshwater species rear in the stream immediately adjacent to the Ethylene Project site. The stream is an important rearing stream for juvenile chinook.

Therefore, an assessment must carefully analyze the impacts of the projects on water, aquatic life and especially fish. Fraser River fish populations are in crisis – "[m]ore than 20 runs in the Fraser River are headed for endangered status, including those of the sockeye, chinook, and coho" salmon.[49] Thus, potential impacts on the precious salmon resource must be carefully studied.

For example, it has been estimated that the raw water supply needed by the initial proposed ethylene facility is between 600-650 cubic metres of water per hour. This equates to approximately six Olympic-sized pools every 24 hours. WCOL has indicated that they wish to draw this amount from groundwater. The impact of proposed water extraction/usage of all three projects on fish, streams and groundwater quantity and quality must be carefully evaluated. [50]

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[44] Industrial Fire World Staff "Explosion at Chinese Polyethylene Plant Kills 7," (2020 November 13) Industrial Fire World, online: <https://www.industrialfireworld.com/582574/explosion-at-chinese-polyethylene-plant-kills-7>.
[45] World Wildlife Fund, "Environmental Concerns Mount Over Toxic Spill in China," (2005 November 24), online: <https://wwf.panda.org/wwf_news/?51700/Environmental-concerns-mount-over-toxic-spill-in-China>.
[46] Amy Smart, "'It was huge': Enbridge gas pipeline ruptures, sparking massive fire and evacuation north of Prince George, B.C.," *Financial Post* (2018 October 10), online: <https://financialpost.com/news/newsalert-enbridge-pipeline-ruptures-sparks-fire-near-prince-george-b-c-2>.
[47] Andrew Kurjata, "A year after Prince George pipeline blast, B.C. First Nation wants answers Social Sharing", *CBC News* (2019 October 9), online: <https://www.cbc.ca/news/canada/british-columbia/enbridge-pipeline-prince-george-one-year-1.5313608>.
[48] Fraser Basin Council and BC Parks, "The Fraser River – A Canadian Heritage River Story Map," Canadian Heritage Rivers, online: <https://www.arcgis.com/apps/MapSeries/index.html?appid=65d67aa847fe46e0a454b7efe5209ce5>.
[49] Sarah Grochowski, "Imminent extinction of Interior steelhead runs foretells what's to come for Fraser River salmon: experts", *Vancouver Sun* (2021 August 13), online: <https://vancouversun.com/news/imminent-extinction-of-interior-steelhead-runs-foretells-whats-to-come-for-fraser-river-salmon-experts>.
[50] West Coast Olefins Ltd. "West Coast Olefins Project Preliminary project description – Revision 1" (2019 September 12) at Table 3.3, online (pdf):

The water pollution that will come from the projects must also be scrutinized. Both water extraction and water pollution may pose risks to invaluable fish stocks in the area.

Two fish listed under the *Species at Risk Act* (SARA) are present in connected waters: White Sturgeon (Upper Fraser NSP and Nechako White NSP) and Bull Trout. They both frequent the Fraser and Nechako rivers in and around Prince George and are among many other species that could be negatively impacted by various aspects of this proposed project. Note that although sturgeon do not directly use the stream mentioned, they do feed on migrating chinook salmon.[51]

Note that fugitive plastics themselves may pose a potential threat to fish populations and their habitat. A great deal of new research is being done on this question. For example, research on the impacts of microplastics on aquatic environments and fish is underway at the Experimental Lakes Area in Ontario.[52] Microplastic pollutants in the aquatic environment pose a risk of bio-accumulating in the smaller organisms in the stream, and then into salmon, sturgeon and other fish.[53]

The end product of the planned plastics facility will also fuel the global plastic pollution problem, and impact fish in that fashion. Already, In the Strait of Georgia over 3,000 particles of microplastic per cubic meter of seawater are being found;[54] and a recent study estimated that returning BC adult salmon may be ingesting up to 90 particles of plastic per day.[55]

An independent expert panel must carefully weigh potential impacts on waters and fish.

An Exacerbating Factor – the specific location of the projects

Negative social, health, economic and environmental impacts of the petrochemical complex could well be exacerbated by the specific location of the facilities. For example, the currently proposed Ethylene Project site is far too close to residential areas and well-used greenways in Prince George. It is located less than three kilometres away from residential areas with schools and playgrounds. It is also adjacent to trails and greenspaces that connect recreation and leisure (e.g. cycling; running; dryland ski training).

The site is adjacent to the Fraser River which is a key waterway for the local area, as well as a waterway of concern due to downstream impacts on fish populations. The proposed site is within City of Prince George boundaries and partly falls within the Agricultural Land Reserve.[56]

<https://projects.eao.gov.bc.ca/api/public/document/5d7bc9fb26583700218b9080/download/Preliminary%20Project%20Description_Issued_Rev1_Sept%2012.pdf>.

[51] Fisheries and Oceans Canada, "Aquatic Species at Risk found in Canadian Waters," online: <https://www.dfo-mpo.gc.ca/species-especes/sara-lep/identify-eng.html?province=British%20Columbia>.

[52] International Institute for Sustainable Development – Experimental Lakes Area, "Measuring the Impact of Microplastics on Fresh Water" (2019 April 16), online: < https://www.iisd.org/ela/research/current-research/measuring-impact-microplastics-fresh-water/>. Also see: Therese M. Karlsson et al. "The unaccountability case of plastic pellet pollution" (2018) 129:1 Marine Pollution Bulletin 52-60, online: <https://www.sciencedirect.com/science/article/pii/S0025326X18300523>.

[53] Michaela Miller, Mark Hamman and Frederieke J Kroon, "Bioaccumulation and biomagnification of microplastics in marine organisms: A review and meta-analysis of current data"15(10) PLoS ONE, online (pdf): <https://journals.plos.org/plosone/article/file?id=10.1371/journal.pone.0240792&type=printable>.

[54] Jean-Pierre Desforges et al., "Widespread Distribution of Microplastics in Subsurface Seawater in the *NE Pacific Ocean: Marine Pollution Bulletin*, 79 (2014) 94-99, at pp.94-98.

[55] Jean-Pierre Desforges et al., "Ingestion of Microplastics by Zooplankton in the Northeast Pacific Ocean," *Archives of Environmental Contamination and Toxicology*, June 12, 2015, Abstract.

[56] See: Provincial Agricultural Land Commission, "ALR & Maps," online: <https://www.alc.gov.bc.ca/alc/content/alr-maps>.

The Ethylene Project site is simply not suitable for a large petrochemical plant and the potential vehicular traffic, resulting pollution, and other risks. Indeed, it is arguable that this proposed land use and location precludes the ideal vision of Prince George in 2040 as articulated in the City's Official Community Plan as "a model for sustainable Canadian cities" with a healthy local environment and spectacular natural setting listed as two key points.[57]

Similar serious questions are being raised about the appropriateness of the Agricultural Land Reserve site recently announced for the Pineview Natural Gas Liquid Recovery Project.[58]

In sum, the siting of all the projects must be seriously assessed by experts – to ensure that impacts on neighbours, farm land, waterways and community health are accurately measured and considered.

Social impacts associated with temporary "man camps" in the construction phase

Scholars have documented that temporary industrial "man camps" often used to build similar projects have negative social impacts on the communities around them – including high rates of violence among men living in work camps, and documented increases in domestic violence.[59]

Documented worker experiences have also noted particular stresses, strains and challenges associated with work camps. These include transportation logistics, financial impacts, and safety. Related jobs in the construction phase can come with significant costs for individuals and community.[60]

Notably, the National Inquiry into Missing and Murdered Indigenous Women and Girls, resulted in several calls to action requesting mitigation of the negative impacts of resource-extraction and development projects, on the safety and security of Indigenous women, girls, and 2SLGBTQQIA people.[61] The National Inquiry heard testimony that resource extraction projects can cause an increase in violence against Indigenous women in several ways – and contribute to transience of workers, harassment and assault at the workplace, substance abuse and addictions, and economic insecurity.[62]

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[57] City of Prince George, "Official Community Plan Bylaw No. 8383" (2011) at p. 20, online (pdf): <https://bylaws.princegeorge.ca/Modules/bylaws/Bylaw/Download/df8353e7-7824-49d6-92a4-98de997eff03>.

[58] Caden Fanshaw, "'This is not the right place for it': Pineview residents upset at possibility of new Westcoast Olefins plant," CKPGToday.ca (2021 July 28), online: <https://ckpgtoday.ca/2021/07/28/this-is-not-the-right-place-for-it-pineview-residents-upset-at-possibility-of-new-westcoast-olefins-plant/>.

[59] Kerry Carringtong, Alison McIntosh, and John Scott. "Globalization, Frontier Masculinities and Violence: Booze, Blokes and Brawls." (2010) 50:3 The British Journal of Criminology 393-413, online: <https://academic.oup.com/bjc/article/50/3/393/468175>. Also see: First Peoples Worldwide, "Violence from Extractive Industry 'Man Camps' Endangers Indigenous Women and Girls," First Peoples Worldwide-University of Colorado Boulder (2020 january 29), online: <https://www.colorado.edu/program/fpw/2020/01/29/violence-extractive-industry-man-camps-endangers-indigenous-women-and-children>.

[60] Laura Ryser, Sean Starkey, & Greg Halseth, "The workers' perspective: The impacts of long distance labour commuting in a northern Canadian small town" (2016) 3:3 The Extractive Industries and Society 594-605, online: <https://www.sciencedirect.com/science/article/pii/S2214790X16300120>.

[61] See Calls for Justice 13.1-13.5: Canada, National Inquiry Into Missing and Murdered Indigenous Women and Girls, *Reclaiming Power and Place: The Final Report of the National Inquiry into Missing and Murdered Indigenous Women and Girls – Calls for Justice* (2019), online: <https://www.mmiwg-ffada.ca/wp-content/uploads/2019/06/Calls-Web-Version-EN.docx>.

[62] Canada, National Inquiry Into Missing and Murdered Indigenous Women and Girls, *Reclaiming Power and Place: The Final Report of the National Inquiry into Missing and Murdered Indigenous Women and Girls – Volume 1A* (2019) at 584, online: <https://www.mmiwg-ffada.ca/wp-content/uploads/2019/06/Calls-Web-Version-EN.docx>.

Careful assessment is needed to consider the potential negative social impacts of temporary work camps on both workers and on Indigenous and settler communities.

A FUNDAMENTAL LOCAL ISSUE: WILL THIS PETROCHEMICAL COMPLEX FORECLOSE AN ALTERNATIVE PATH FOR PRINCE GEORGE – ONE THAT WOULD BE ECONOMICALLY, SOCIALLY AND ENVIRONMENTALLY SUPERIOR?

Once dependent on forestry and other extractive industries, Prince George is diversifying, and becoming arguably one of the hottest technology centres in North America. Young entrepreneurs are finding Prince George to be ideal, as it is affordable and offers a desirable lifestyle. This makes Prince George appealing for young start-up companies.

"We are the small but growing Silicon Valley of the North," says Will Cadell, CEO at Sparkgeo, a Prince George company building cutting-edge geospatial technology for companies around the world. Entrepreneurial start-up firms building a cutting-edge 21st century economy are increasingly open to locating in modern Prince George.[63]

The City has been partnering with local non-profits and organizations to re-brand Prince George as a desirable place to work and live.[64] The City Official Community Plan highlights that the diversification of the economy over the last two decades has provided stability – and that future growth in a variety of sectors should meet standards for environmental, social and economic returns.[65] But the City will have difficulty overcoming the old "heavy industry town" reputation if the proposed complex is approved. The City would then be less desirable to those seeking a quality, livable, family-friendly environment.

In the long run, the degradation of the natural environment could be *economically* damaging to Prince George. It could destroy the potential to attract other sectors, jobs, and talent to the City:

> *In recent years, cities that have experienced the strongest economic growth have tended to be the most livable – cities such as Vancouver, Victoria, Seattle and Portland. The chief economist for one of California's largest corporations has found that corporate decision-makers consistently rank the quality of an area's physical environment as one of the top two factors in siting an enterprise, and surveys support that view.* [66]

Recent surveys indicate that the University of Northern British Columbia will likely suffer if the proposed project proceeds. In early days at UNBC (1992-1994), it was difficult to recruit professors and students to come to "stinky, dirty" Prince George. Decades of hard work is starting to change the City's reputation.

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[63] BC Business, "Startup Businesses are Finding Happy Homes in Prince George," online: <https://www.bcbusiness.ca/startup-businesses-are-finding-happy-homes-in-prince-george>.
[64] For example, see: City of Prince George, "Move Up Prince George," posted on *Facebook,* online: <https://www.facebook.com/MoveUpPG/>.
[65] City of Prince George, "Official Community Plan Bylaw No. 8383 – Part C" (2011) at p. 25, online (pdf): <https://www.princegeorge.ca/Business%20and%20Development/Documents/Planning%20and%20Development/OCP/BL8383-BYLAW-PART-C.pdf>.
[66] Commission on Resources and Environment, Calvin Sandborn, *Green Space and Growth*, March 1996, p. 4.

However, a return to the "dirty town" reputation would place both the local University and college at risk.[67]

In recent years, the City has tried to attract retirees to the community, but retirees are not likely to come – or stay – if the current proposal leads to a large new industrial zone right in the City. The loss of retirees, young entrepreneurs, academics, families, artists and cultural development will detract from the City's growing attractiveness and assets. It will reverse the progress made in recent years to diversify the economy, and ensure a more robust economic future.

At the very least, a thoughtful and independent assessment needs to be done to assess whether approval of the petrochemical complex might actually cause serious *economic and social harm* – by foreclosing a more prosperous and sustainable economic path for the City.

THE SUSTAINABILITY DEAL-BREAKER: THE BROADER IMPLICATIONS OF THE PETROCHEMICAL COMPLEX

The petrochemical complex runs counter to government commitments on climate change and plastics.

This three-part petrochemical complex has broad implications on the province, the nation and the world. An independent panel is needed to analyze the overall project's broad impacts on:

- Climate change – and the province's commitments to address climate change;
- Increasing fracking damage in the northeast of British Columbia;
- Undermining the province's stated commitments to reduce unnecessary plastic products; and
- The province's commitments to reduce plastic waste – and to prioritize plastic recycling over production of virgin plastics.

Will this Project Exacerbate Climate change?

> *Plastic Plants are Poised to be the Next Big Carbon Superpolluters" – Scientific American.* [68]

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[67] See UNBC ENVS 326 course projects 2019. Survey available upon request.

[68] Benjamin Storrrow, "Plastic Plants are Poised to Be the Next Big Carbon Superpolluters" *Scientific American* (2020 January 24), online: <https://www.scientificamerican.com/article/plastics-plants-are-poised-to-be-the-next-big-carbon-superpolluters>. Also see: Reid Frazer, "The US Natural Gas Boom is Fueling a Global Plastics Boom" *NPR* (2019 November 15), online: <https://www.npr.org/2019/11/15/778665357/the-u-s-natural-gas-boom-is-fueling-a-global-plastics-boom>; Earthworks "Fracking for Plastic," online: <https://www.earthworks.org/issues/fracking-for-plastic/>; Center for International Environmental Law, "How Fracked Gas, Cheap Oil, and Unburnable Coal are Driving the Plastics Boom," online (pdf): <https://www.ciel.org/wp-content/uploads/2017/09/Fueling-Plastics-How-Fracked-Gas-Cheap-Oil-and-Unburnable-Coal-are-Driving-the-Plastics-Boom.pdf>.

All three proposed projects will encourage more natural gas fossil fuel utilization. And the polyethylene (plastics) plant is particularly problematic. A rapidly expanding plastics industry is a major threat to world climate. Currently, plastics-related industry consumes 7-8% of the world's oil and gas production.[69] By 2050 it has been estimated that the plastics industry overall could be consuming 15% of the global annual carbon budget.[70]

Currently, the oil and gas industry is encouraging massive increases in plastics production – trying to somehow sell the glut of fracked gas and oil now flooding the market. But that is bad news for those who worry about the climate that their grandchildren will inherit. The problem is that new petrochemical/plastic plants create massive, permanent new sources of greenhouse gases – in a world where the head of the International Energy Association warns that we simply cannot meet long-term global CO_2 emission goals if we build *any* new emitting infrastructure.[71]

In spite of this climate imperative, a Yale University journal has revealed that the oil and gas industry is rapidly expanding *plastic production* in order to replace the oncoming phase-out of fossil fuels for transportation and other uses:

> *Companies like ExxonMobil, Shell, and Saudi Aramco are ramping up output of plastic — which is made from oil and gas, and their byproducts — to hedge against the possibility that a serious global response to climate change might reduce demand for their fuels, analysts say. Petrochemicals, the category that includes plastic, now account for 14 percent of oil use, and are expected to drive half of oil demand growth between now and 2050, the International Energy Agency (IEA) says. The World Economic Forum predicts plastic production will double in the next 20 years.*[72]

Scientific American recently published an article entitled: "Plastic Plants are Poised to be the Next Big Carbon Superpolluters." The article points out:

> *A boom in petrochemical plants driven by cheap natural gas could lock in greenhouse emissions for decades to come.*

Scientific American goes on to quote lawyer Steven Feit:

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[69] Plastics consume 4% of the world's oil and gas production, and an additional 3-4% of world oil and gas is used for plastics manufacture. See: Jefferson Hopewell, Robert Dvorak and Edward Kosior, "Plastics recycling: challenges and opportunities" (2009) 364:1526 Philosophical Transactions of the Royal Society B 2115, online (pdf): <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2873020/pdf/rstb20080311.pdf>.

[70] FN World Economic Forum, "The New Plastics Economy: Rethinking the future of plastics" (2016) at p. 22, online (pdf): <http://www3.weforum.org/docs/WEF_The_New_Plastics_Economy.pdf>. Also see: Environmental Law Centre, *Seven Reforms to Address Marine Plastic Pollution,* Meaghan Partridge and Calvin Sandborn, (Report) online: <http://www.elc.uvic.ca/wordpress/wp-content/uploads/2017/08/2017-01-11-MarinePlastics_2017Oct23.pdf> at p. 7.

[71] Faith Birol, executive director of the International Energy Agency has stated that in order to meet global CO2 emission goals, "[w]e have no room for anything [new] that emits CO2 emissions." See: Adam Vaughn, "World has no capacity to absorb new fossil fuel plants, warns IEA" *The Guardian* (2018 November 13), online: <https://www.theguardian.com/business/2018/nov/13/world-has-no-capacity-to-absorb-new-fossil-fuel-plants-warns-iea>.

[72] Beth Gardiner, "The Plastics Pipeline: A Surge of New Production Is on the Way", Yale Environment 360, (2019 December 19) online: <https://e360.yale.edu/features/the-plastics-pipeline-a-surge-of-new-production-is-on-the-way>.

Plastic is fossil fuel in another form. Everything that happens before you see that plastic on the shelf is emissions intense. It releases all manner of pollutants and toxic chemicals…At the top level, dealing with the climate crisis requires dealing with the plastics crisis. [73]

A recent Earthjustice report encapsulated the issue:

Petrochemicals are a carbon bomb that threaten to cancel out the progress we've made on solving the climate crisis… New petrochemical facilities would extend the life of the oil and gas industry and undermine efforts to keep fossil fuels in the ground.

For example, just one proposed petrochemical complex in Ohio would require thousands of shale gas wells to be drilled and fracked to keep it supplied with raw materials. Petrochemical facilities are energy-intensive and dump an enormous amount of carbon pollution into the air. For example, Louisiana's Formosa mega-complex alone would emit 13.6 million tons of carbon pollution every year — the equivalent of adding 2.8 million cars to the road.

After they are produced, petrochemical products continue to fuel the climate crisis. For example, nearly 12% of plastic waste is incinerated, releasing more greenhouse gases as well as dangerous toxins. New research suggests that plastic releases greenhouse gases as it degrades — representing a potentially vast and uncontrollable source of emissions.[74]

Indeed, the multitude of new petrochemical/plastic plants may make it impossible to deal with the climate challenge. Judith Enck, a former regional director for the U.S. Environmental Protection Agency and founder of Beyond Plastics, has warned:

There are a lot of these facilities that are in the permitting process. We're pretty close to it all being too late,' 'If even a quarter of these ethane cracking facilities are built, it's locking us into a plastic future that is going to be hard to recover from.[75]

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[73] Benjamin Storrow, "Plastic Plants are Poised to Be the Next Big Carbon Superpolluters" *Scientific American* (2020 January 24), online: <https://www.scientificamerican.com/article/plastics-plants-are-poised-to-be-the-next-big-carbon-superpolluters>. Also see: Reid Frazer, "The US Natural Gas Boom is Fueling a Global Plastics Boom" *NPR* (2019 November 15), online: <https://www.npr.org/2019/11/15/778665357/the-u-s-natural-gas-boom-is-fueling-a-global-plastics-boom>; Earthworks "Fracking for Plastic," online: <https://www.earthworks.org/issues/fracking-for-plastic/>; Center for International Environmental Law, "How Fracked Gas, Cheap Oil, and Unburnable Coal are Driving the Plastics Boom," online (pdf): <https://www.ciel.org/wp-content/uploads/2017/09/Fueling-Plastics-How-Fracked-Gas-Cheap-Oil-and-Unburnable-Coal-are-Driving-the-Plastics-Boom.pdf>.

[74] Earthjustice, "How Big Oil is Using Toxic Chemicals as a Lifeline – and How We Can Stop It" (2020 July 2), online: <https://earthjustice.org/features/petrochemicals-explainer>.

[75] Beth Gardiner, "The Plastics Pipeline: A Surge of New Production Is on the Way," Yale Environment 360, (2019 December 19), online: <https://e360.yale.edu/features/the-plastics-pipeline-a-surge-of-new-production-is-on-the-way>. Note that excess North American fracked natural gas is driving this boom, not only in North America, but also in Europe. See: Beth Gardiner, "Europe Plastics Industry About to Boom. US Fracking is Driving It" *National Geographic* (2021 March 25), online: <https://www.nationalgeographic.com/environment/article/europe-plastics-industry-about-to-boom-us-fracking-driving-it>.

[Note that the proposed petrochemical complex is just such an 'ethane cracking facility.' See the WCOL flow charts above in Figures 1 and 2.]

British Columbia has committed to reducing greenhouse gas emissions. Yet the proposed project involves building **long-term infrastructure that entrenches future consumption of fossil fuels**. A decision to approve this project will directly impact the greenhouse gas emissions from British Columbia – not just now, but in 2050 and beyond. Therefore, the decision to approve the combined petrochemical complex should not be made lightly. **The fact is, approval of this complex may be one of the most consequential climate change decisions your government will ever make.**

As University of Toronto science Professor Laura Tozer has warned:

> *The evidence is clear that owners of fossil fuel assets and infrastructure obstruct effective climate policy. Every time we invest in infrastructure or institutions whose very existence depends on continuing to use fossil fuels, it makes it harder for Canada to tackle the climate crisis.*[76]

If your government is serious about its avowed commitment to reducing greenhouse gases, this proposed long-term natural gas-consuming infrastructure should not be approved. At the very least, approval should not be given without the strictest possible scrutiny. This multi-billion-dollar petrochemicals complex will operate for decades and decades – long after much of the developed world expects to forsake fossil fuels entirely.

As governments and financial institutions begin to move away from large fossil fuel investments, massive new infrastructure of this kind should only be approved after the most rigorous assessment of costs and benefits.

Surely a panel of experts must consider the long-term, global climate change impacts of this petrochemical complex. For example, it is estimated that the larger Formosa petrochemical complex is equivalent to adding 2.8 million cars to the road. Just how many cars is the proposed Prince George complex equivalent to? We need to know, before this gets approved.

The catastrophic climate change impacts that BC has suffered in recent years – from the mountain pine beetle scourge that killed our pine forests, to the drought that is wiping out salmon stocks, to the apocalyptic summer that Interior British Columbians suffered this summer – demands nothing less.

Will This Project Increase Fracking Damage?

> *With natural gas prices low, many fracking operations are losing money, so producers have been eager to find a use for the ethane they get as a byproduct of*

[76] Professor Laura Tozer, "Canada Needs to Embrace its Fossil-Free Energy Future" Corporate Knights (2021 March 17), online: <https://www.corporateknights.com/channels/energy/canada-needs-to-embrace-its-fossil-free-energy-future-16159829/>.

> *drilling…'they're looking for a way to monetize it, Feit said…'You can think of plastic as kind of subsidy for fracking.'* *Beth Gardner,* Yale Environment 360[77]

The natural gas used for this proposed project comes at a steep environmental cost. The environmental toll imposed by that natural gas production must be fully considered in any fair assessment of the impact of the proposed petrochemical complex. Fracking operations that create the inputs for this project cause widespread environmental damage:

- The numerous gas wells, pipelines, seismic exploration lines, and service roads necessary to produce natural gas will fragment wildlife habitat. This profoundly impacts grizzly and caribou populations.
- Fracking operations extract precious water from watersheds – and damage streams, wetlands and fish populations.
- Water used in the fracking process can be highly contaminated with salts, radioactive materials, arsenic, benzene mercury and other substances.
- Fracking damages air quality – and puts nearby human populations at risk from lethal sour gas and other toxins.
- Recent research indicates that fracking may be a significant contributor to climate change because it leads to leaks of methane gas, an extraordinarily powerful greenhouse gas.

Other environmental harms caused by fracking are documented in a previous Environmental Law Centre study.[78]

Clearly, the impacts of increased fracking should be considered by the panel of experts.

Will this Project Undermine Provincial Efforts to Reduce Plastic Waste?

Plastic waste consumes vast amounts of energy – it fills our landfills, clogs our storm water systems, and litters our landscapes. Other damage created by the end product of plastic production is well documented:

> *The world's oceans are choking on plastic. Every year millions of tons of plastic straws, plastic bags, food wrappers, bottles, Styrofoam, plastic fishing gear and other plastics cascade into the sea. This trash kills countless fish, more than a million seabirds and 100,000 marine mammals annually. Sea turtles eat plastic bags, mistaking them for jellyfish. Six-pack rings strangle gulls and herons. Plastic bags entangle and drown seals and dolphins. Whales become entangled in plastic nets – or ingest so much plastic debris that their guts burst.*

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[77] Beth Gardiner, "The Plastics Pipeline: A Surge of New Production Is on the Way," Yale Environment 360, (2019 December 19) online: <https://e360.yale.edu/features/the-plastics-pipeline-a-surge-of-new-production-is-on-the-way>.

[78] For a complete compendium of impacts from fracking see the ELC's "Request that Minister Polak order a Strategic Economic and Environmental Assessment of Liquid Natural Gas Development in British Columbia, pursuant to Section 49 of the *Environmental Assessment Act*," online (pdf) at: <https://elc.uvic.ca/wordpress/wp-content/uploads/2015/01/Strategic-Economic-and-Environmental-Assessment-of-LNG_2013-02-01_2013Aug.pdf>.

> *Worse still, plastic eventually breaks down into microparticles that are now everywhere. And our children are eating it. Microplastics are widely found in tap water and bottled water. Most commercial sea salt contains plastic particles. British Columbia scientists have found more than 3,000 plastic microparticles per cubic metre of water in the Strait of Georgia. One expert estimates that returning B.C. salmon ingest up to 90 plastic particles a day. In a recent survey, the average B.C. shellfish contained eight plastic particles – particles that may contain endocrine inhibitors and carcinogens.*
>
> *And this problem is rapidly growing. With plastic production doubling every 20 years, Royal Society research estimates that by 2050 the oceans could contain more plastic than fish.*[79] *Margaret Atwood and Calvin Sandborn*[80]

In 2018 the Parliament of Canada passed a remarkable *unanimous* resolution to deal with such wasteful plastic pollution.[81] This led the Government of Canada to adopt a National Plastics Reduction Strategy and to commit to a ban harmful single-use plastics.[82] Similar concerns led the Government of British Columbia to facilitate local government bans on harmful single-use plastic items – and to promise a legal framework to provide for province-wide bans of single-use plastic items.[83]

Independent experts on the requested assessment panel will need to analyze a critically important strategic question: Will creation of this massive new petrochemical/plastics production facility undermine government policy commitments to reduce production of unnecessary plastic products?

Will this Project Undermine Efforts to Encourage Plastic Recycling?

A related question arises. It is now widely recognized that increasing recycling of plastics (and other materials) is desirable. This is why the European Union and the Government of Canada are encouraging the development of a Circular Economy.[84]

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[79] The facts cited in this quote are all documented in Environmental Law Centre, *Seven Reforms to Address Marine Plastic Pollution,* Meaghan Partridge and Calvin Sandborn (Report), online: <http://www.elc.uvic.ca/wordpress/wp-content/uploads/2017/08/2017-01-11-MarinePlastics_2017Oct23.pdf> at pp.4-7.

[80] Margaret Atwood and Calvin Sandborn, "Can Canada Re-invent the Plastic Economy?," *Globe and Mail* (2018 May 2), online: <https://www.theglobeandmail.com/opinion/article-can-canada-reinvent-the-plastic-economy/>.

[81] CBC News, "BC MP celebrates 'tremendous' victory as plastics pollution motion passes House" *CBC News* (2018 December 5), online: <https://www.cbc.ca/news/canada/british-columbia/b-c-mp-celebrates-tremendous-victory-as-plastics-pollution-motion-passes-house-1.4934361>.

[82] Charlie Smith, "Trudeau promises crackdown on plastic wastes – months after NDP MP won unanimous support for action" Straight Talk (2019 June 10), online: <https://www.straight.com/movies/1252561/trudeau-promises-crackdown-plastic-wastes-months-after-ndp-mp-won-unanimous-support>.

[83] BC Ministry of Environment and Climate Change Strategy News Release, "Province approves local bans, takes action on plastics," September 12, 2020, online: <https://archive.news.gov.bc.ca/releases/news_releases_2017-2021/2020ENV0051-001715.htm>.

[84] See, for example, Ellen MacArthur Foundation "Towards the Circular Economy: Business rationale for an accelerated transition," (2015 December 2)(Report), online: <https:/www.ellenmacarthurfoundation.org/publications/towards-a-circular-economy-business-rationale-for-an-accelerated-transition>, and Ellen MacArthur Foundation, "The New Plastics Economy: rethinking the future of plastic & catalyzing action," (2017 December 13)(Report), online:

Currently, only 9% of plastic waste in Canada gets recycled, and approximately 87% of plastic waste in Canada ends up in the landfill or leaked into the environment.[85] In 2016, plastic waste amounted to a loss of economic value equivalent to approximately $7.8 billion CAD.[86] More than 90% of the plastic that is produced is new plastic, using virgin fossil feedstocks rather than recycled plastics in the manufacturing process.[87]

It is clearly necessary to supplant the current wasteful linear plastics supply chain ("manufacture, use, throwaway") with a *circular* plastics economy. If we produce plastic products, they must be recycled or reused. The Government of Canada has clearly recognized the need to prioritize plastic recycling.[88]

However, perhaps the single biggest barrier to effective recycling is the fact that production of virgin plastics from oil and gas is currently cheaper than recycling.[89] Experts agree that recycled plastic needs to be made more economically competitive than virgin plastics. Otherwise, recycling efforts will likely fail.

To address this market disadvantage that recycling faces, many jurisdictions have designed taxes and other policies to *discourage the production of virgin plastics* from fossil fuels – exactly the kind of plastic production contemplated by the proposed petrochemical complex.[90] Discouraging this kind of virgin plastic production is necessary, for recycling efforts to succeed. The Organization for Economic Co-operation and Development (OECD) has stated:

<https://www.ellenmacarthurfoundation.org/publications/the-new-plastics-economy-rethinking-the-future-of-plastics-catalysing-action>. Also see: Organization for Economic Co-operation and Development (OECD) "Improving Markets for Recycled Plastics: Trends, Prospects and Policy Responses," (2018 May 24) online: <https://www.oecd.org/env/improving-markets-for-recycled-plastics-9789264301016-en.htm>; Institute for European Environmental Policy "EPR in the EU Plastics Strategy and the Circular Economy: A focus on plastic packaging," (2017 November 9) online (pdf): <https://ieep.eu/uploads/articles/attachments/95369718-a733-473b-aa6b-153c1341f581/EPR%20and%20plastics%20report%20IEEP%209%20Nov%202017%20final.pdf>. A recent discussion from Environment and Climate Change Canada states that a plastic ban "…complements government and business actions to transition to a more circular economy that will not only reduce pressure on the environment, but also increase competitiveness, stimulate innovation and boost economic growth by creating new jobs." See: Environment and Climate Change Canada, "Discussion on A Proposed Integrated Management Approach to Plastic Products to Prevent Waste and Pollution," (2021 July 12), online: <https://www.canada.ca/en/environment-climate-change/services/managing-reducing-waste/consultations/plastics.html>.

[85] Deloitte & Cheminfo Services Inc., "Economic Study of the Canadian Plastic Industry, Markets and Waste," (Environment and Climate Change Canada: 2019), online: <http://publications.gc.ca/collections/collection_2-19/eccc/En4-366-1-2019-eng.pdf>.

[86] Deloitte & Cheminfo Services Inc., "Economic Study of the Canadian Plastic Industry, Markets and Waste," (Environment and Climate Change Canada: 2019), online: <http://publications.gc.ca/collections/collection_2-19/eccc/En4-366-1-2019-eng.pdf>.

[87] Ellen MacArthur Foundation, "The New Plastics Economy: rethinking the future of plastic & catalyzing action," (2017 December 13) (Report), online: <https://www.ellenmacarthurfoundation.org/publications/the-new-plastics-economy-rethinking-the-future-of-plastics-catalysing-action>.

[88] For example, an Environment and Climate Change Canada News Release, May 31, 2021 states: "The Government of Canada is committed to achieving zero plastic waste by 2030, and is working to take action to reduce plastic pollution across the country and to create a circular economy for plastics."

[89] Jillian Ambrose, "War on plastic waste faces setback as cost of recycled material soars," *The Guardian* (2019 October 13), online: <https://www.theguardian.com/environment/2019/oct/13/war-on-plastic-waste-faces-setback-as-cost-of-recycled-material-soars>.

[90] See the following ELC Report: Erin Gray, Calvin Sandborn, Jenny YC Lee, Alex McArdle, "Enhancing Plastic Recycling in Canada," (2020 August) at pp.22-26, online (pdf): <https://elc.uvic.ca/wordpress/wp-content/uploads/2020/08/2019-03-06-Enhancing-Plastic-Recycling-in-Canada-FINAL-FOR-WEBSITE-AND-PUBLIC.pdf>.

> *Governments of G7 countries could address these challenges [of virgin plastics being priced too low] through policy interventions that aim to level the playing field between virgin and recycled plastics or support the market for recycled plastics. They include: Taxes on the use of virgin plastics or differentiated value added taxes for recycled plastics or plastic products.*[91]

Yet, there is a real risk that government support for the proposed project would advantage *the continued expansion of virgin plastic production* – which will undercut the recycling we need, if we are to create a circular economy.

The expert panel should consider whether establishment of this petrochemical complex – and its production of yet more virgin plastic – will ultimately doom Canada's plastic recycling efforts.

A CRITICAL FINAL ISSUE: WILL THIS PETROCHEMICAL COMPLEX BACKFIRE ECONOMICALLY?

The Economic Risk – The Stranded Assets Danger

Investing in fossil fuel infrastructure is a very risky economic move these days. There is a clear danger that such fossil fuel facilities will become unprofitable – or even inoperable – when governments and markets respond to the growing climate emergency. The risk that this petrochemical complex will become a "stranded asset" is growing quickly and dramatically. This outcome could have enormous negative impacts on both the proponent and on British Columbians.

Mark Carney, former governor of the Bank of Canada and the Bank of England has warned that investments in fossil fuel infrastructure are likely to become "worthless" – and warned countries to avoid investing in such infrastructure that could become "stranded."[92] The International Energy Agency notes that large asset managers and asset owners are "facing heightened scrutiny of investments in the fossil fuel industry."[93] The executive vice-president of the European Commission, Frans Timmermans, has put the point bluntly:

> *There's no point building assets now that will be of no use in a few years.*[94]

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[91] Erin Gray, Calvin Sandborn, Jenny YC Lee, Alex McArdle, "Enhancing Plastic Recycling in Canada," (2020 August) at p. 25, online (pdf): <https://elc.uvic.ca/wordpress/wp-content/uploads/2020/08/2019-03-06-Enhancing-Plastic-Recycling-in-Canada-FINAL-FOR-WEBSITE-AND-PUBLIC.pdf>.

[92] Andrew Sparrow, "Firms must justify investment in fossil fuels, warns Mark Carney," *The Guardian* (2019 December 30), online: <https://www.theguardian.com/business/2019/dec/30/firms-must-justify-investment-in-fossil-fuels-warns-mark-carney>.

[93] International Energy Agency (IEA) and Centre for Climate Finance & Investment, "Energy Investing: Exploring Risk and Return in the Capital Markets" (2020 June, 2nd Edition) at p. 5, online (pdf): <https://iea.blob.core.windows.net/assets/3d8c7c6f-bd94-43b8-94ef-d30135c0c776/Energy_Investing_Exploring_Risk_and_Return_in_the_Capital_Markets.pdf>.

[94] Rachel Morrison "Gas is the New Coal With Risk of 100 Billion in Stranded Assets", *Bloomberg News* (2021 April 17), online: <https://www.bnnbloomberg.ca/gas-is-the-new-coal-with-risk-of-100-billion-in-stranded-assets-1.1591499>.

Similarly, the vice-president of the European Investment Bank, Andrew McDowell has issued a similar warning against the risk of investing in "stranded" fossil fuel infrastructure, stating:

> *Investing in new fossil fuel infrastructure like liquefied natural gas terminals is increasingly an economically unsound decision.*[95]

The Intergovernmental Panel on Climate Change (IPCC) warns that mitigation efforts necessary to meet the Paris Agreement target of limiting global warming to 1.5°C will create risks for places like Canada that depend heavily on fossil fuels for revenue and employment.[96] The IPCC's warns that innovations associated with decarbonizing the economy "may leave firms and utilities with stranded assets, as the transition can happen very quickly."[97] The transition may lead to certain fossil fuels being rendered "unburnable" and the associated industrial assets becoming "obsolete."[98]

Investors have been wary of investing in coal for some time now, and the European Investment Bank President Werner Hoyer warns that natural gas is now facing a similar fate:

> *To put it mildly, gas is over. Without the end to the use of unabated fossil fuels, we will not be able to reach the climate targets.*[99]

Indeed, financial market regulators, in Canada and globally, are increasingly concerned about risky fossil fuel investments. For that reason, regulators are moving in the direction of mandating the disclosure of climate-change related risks of various investments. This will allow investors to more accurately assess whether risks associated with climate change may diminish the return on their investments. Many financial institutions now require climate change related financial risk disclosure from clients – and the Government of Canada is considering requiring such disclosures by law.[100]

Note that the Expert Panel on Sustainable Finance commissioned by Environment and Climate Change Canada and Finance Canada, highlights that "[w]hile there is uncertainty as to how or when impacts will

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[95] Matthew Green, "Global LNG projects jeopardized by climate concerns, pandemic delays – report" *Reuters* (2020 July 6), online: <https://www.reuters.com/article/us-climate-change-gas-idUKKBN247303>.

[96] IPCC, "Global Warming of 1.5°C.An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty" (2018) at p. 21, online (pdf): <https://www.ipcc.ch/site/assets/uploads/sites/2/2019/06/SR15_Full_Report_High_Res.pdf>.

[97] IPCC, "Global Warming of 1.5°C.An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty" (2018) at p. 323, online (pdf): <https://www.ipcc.ch/site/assets/uploads/sites/2/2019/06/SR15_Full_Report_High_Res.pdf>.

[98] IPCC, "Global Warming of 1.5°C.An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty" (2018) at p. 323, online (pdf): <https://www.ipcc.ch/site/assets/uploads/sites/2/2019/06/SR15_Full_Report_High_Res.pdf>.

[99] Rachel Morrison "Gas is the New Coal With Risk of 100 Billion in Stranded Assets", *Bloomberg News* (2021 April 17), online: <https://www.bnnbloomberg.ca/gas-is-the-new-coal-with-risk-of-100-billion-in-stranded-assets-1.1591499>.

[100] See: Eli Monas, Tyson Dyck, and William R Walters, "In pursuit of a climate change risk framework for Canada's financial institutions", Tory's LLP (2021), online: <https://www.torys.com/insights/publications/2021/03/in-pursuit-of-a-climate-change-risk-framework-for-canadas-financial-institutions> and the final report from the Expert Panel on Sustainable Finance commissioned by ECCC and Finance Canada, "Final Report of the Expert Panel on Sustainable Finance: Mobilizing Finance for Sustainable Growth" (2019), online: <https://www.canada.ca/en/environment-climate-change/services/climate-change/expert-panel-sustainable-finance.html>.

fully manifest, there is no opting-out of climate effects."[101] Many of the policy changes recommended by the Expert Panel involve *mandating and clarifying the assessment and disclosure of climate risks to ensure the prosperity of Canada's financial sector*.

The emerging policies to mandate disclosure of climate risks will almost certainly drive investment away from emissions intensive projects – such as the proposed Prince George petrochemical complex. Just how will WCOL then secure the tens of millions of dollars of sustaining capital investment that CEO, Ken James, notes will be required *annually* to support the petrochemical complex?[102]

The Expert Panel on Sustainable Finance put it well:

> *Moving forward, our essential built and natural infrastructure must be able to both withstand the unpredictable and extreme nature of climate change and contribute to national GHG reduction priorities.*[103]

The proposed petrochemical complex likely meets neither test.

It is incumbent upon Government to obtain an expert assessment of the possibility that this petrochemical project may have to be abandoned during its lifetime – and may become a financial drain on taxpayers, like the $100 million bill that taxpayers are already paying for cleaning up BC oil and gas wells.[104]

Before the Province issues an approval of a project which might become "worthless in a few years," it is incumbent upon Government to seek out expert advice on whether this project risks becoming a "stranded asset."

The independent expert panel needs to analyze whether the petrochemical complex could become a financial albatross to provincial taxpayers. All three projects – all parts of the metaphorical elephant – must be considered. In order to ensure that we are not buying a white elephant, the whole elephant needs to be analyzed.

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[101] Expert Panel on Sustainable Finance commissioned by ECCC and Finance Canada, "Final Report of the Expert Panel on Sustainable Finance: Mobilizing Finance for Sustainable Growth" (2019) at p. 31, online: <https://www.canada.ca/en/environment-climate-change/services/climate-change/expert-panel-sustainable-finance.html>.

[102] Hanna Petersen, "'It's a game changer:' Calgary company plans to build $5.6B petrochemical plant in Prince George*" Prince George* Citizen (2019 July 24) online: <https://www.princegeorgecitizen.com/local-news/calgary-company-to-build-56b-petrochemical-plant-in-prince-george-1602606>.

[103] Expert Panel on Sustainable Finance commissioned by ECCC and Finance Canada, "Final Report of the Expert Panel on Sustainable Finance: Mobilizing Finance for Sustainable Growth" (2019) at p. 48, online: <https://www.canada.ca/en/environment-climate-change/services/climate-change/expert-panel-sustainable-finance.html>.

[104] Taxpayers are already footing the bill for s $100-million fund to clean up dormant oil and gas wells in the province. See: Andrew MacLeod, "Governments Are Making Taxpayers Subsidize Corporate Cleanup of Oil and Gas Wells," *The Tyee* (2021 March 19), online: <https://thetyee.ca/News/2021/03/19/Governments-Make-Taxpayers-Subsidize-Corporate-Cleanup-Oil-Wells/>.

CONCLUSION

In light of the above, it would clearly be in the public interest to have a thorough vetting of the serious potential environmental, social and economic impacts posed by the proposed petrochemical complex. We ask you to appoint an independent panel of experts to conduct an assessment of these issues by way of public hearings and to assess all three interconnected facilities together through a regional assessment.

Respectfully submitted,

Calvin Sandborn, Queen's Counsel

Christa Croos, Articled Student

"*Anthony Carlino*"

Anthony Carlino, Law Student

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Understanding the Environmental Impacts of Chemical Recycling

Ten concerns with existing life cycle assessments

December 2020

Zero Waste Europe

EEB European Environmental Bureau

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Understanding the Environmental Impacts of Chemical Recycling

Ten concerns with existing life cycle assessments

Introduction

Chemical recycling and recovery of plastics often refers to processes such as gasification and pyrolysis, in which polymers are chemically broken down to monomers. These monomers can be used to produce new polymers and plastics, either by reproducing the original or developing new types of polymeric products (Grigore, 2017). However, more often than not, plastic is simply turned to fuel and then burned, releasing the carbon into the atmosphere. This is not defined as recycling in the EU Waste Framework Directive.

Recently, chemical recycling technologies have been promoted as being environmentally friendly, with claims that they can contribute to reducing environmental and climate impacts from plastic. For the purpose of science-based political decisions, it is crucial to have a complete and correct understanding of the true environmental impacts of these technologies.

However, good data on environmental impacts of chemical recycling is difficult to acquire due to the limited maturity of the chemical recycling concept at commercial scale: there are currently no operational plants of significant scale available to recycle plastic to new plastic, despite five decades of attempted effort. Yet, life cycle assessments (LCAs) developed by, or in affiliation with, businesses are being used to make sustainability claims related to these chemical recycling and recovery technologies.

This paper presents key findings from a review of some of the most commonly cited chemical recycling and recovery LCAs, which reveal major flaws and weaknesses regarding scientific rigour, data quality, calculation methods, and interpretations of the results.

LCA is a tool which can contribute to determining favourable technologies through different sustainability impact categories. However, the findings from LCA studies are highly affected by the set of boundaries, assumptions, and data used. Merely changing one variable can sometimes turn the entire results on their head. For this reason, LCA studies are notoriously easy to misinterpret and are sometimes used to draw general conclusions based on assumptions which may only be applicable in a very narrow context, or even incorrect.

Currently, there are no comprehensive and fully independent LCAs on chemical recycling to provide a complete understanding of the environmental impacts. If the EU wants to successfully transition towards a circular and decarbonised economy, priority should be given to prevention and reuse. Subsequently, only the recycling technologies which can or have significant potential to recycle as much material as possible while minimising environmental impacts should be supported, rather than alternatives such as pyrolysis and gasification, which require large amounts of energy.

Recommendations

- **Policy-makers should be cautious towards using chemical recycling LCAs as a basis for decision-making.** In particular, comparative LCAs in which chemical recycling technologies are shown as more favourable than other options should never be interpreted without a full understanding of real life datasets, geographical and system boundaries, assumptions made, as well as calculation methods which may have heavily influenced results. Attention should also be paid to the attribution methods of 'avoided emissions' and the benchmarks to which the technologies are compared.

- **The European Commission should support the development of more independent, transparent, and comprehensive assessments of environmental and climate impacts of chemical recycling based on primary data sources before developing further legislative frameworks incentivising the technologies.** Further attention should also be paid to toxicity and purity levels, as existing LCA studies systematically exclude or fail to fully disclose toxic and harmful contaminants and emissions, both in outputs and emitted during chemical recycling processes. These studies should be guided by a robust methodology for assessing the environmental and climate impacts of chemical recycling, taking into consideration real process yields and all the process steps, including purification and repolymerisation.

- **Investments and EU funds should only support plastic recycling processes with a lower carbon footprint than the production of plastic from virgin feedstock, with consideration to the actual process emissions.** In particular, the accounting of 'avoided emissions' from alternative waste disposal options for plastic, as a way to claim that chemical recycling has a net negative carbon footprint, should be strongly discouraged.

In order to provide a better understanding of the environmental impacts of chemical recycling to inform policy-making or to guide investments, the results of LCA studies must be presented alongside key knowledge on the topic:

- There is currently no large scale industrial chemical recycling plastic-to-plastic plant in operation (Quicker, 2019).

- Chemical recycling is energy-intensive and has multiple intrinsic and ancillary energy demands, which render it unsuitable for consideration as a sustainable technology. Even if the products/byproducts are burned for energy, there isn't a chemical recycling technology that can currently offer a net-positive energy balance (Rollinson and Oladejo, 2020), and there is no evidence that points to an improvement in the foreseeable future.

- Due to its power consumption, chemical recycling is commonly considered to be a low-value form of recycling compared to "recycling as material" (Ministry of Infrastructure and Water Management, the Netherlands, 2017), and leads to significant material losses in the process (Patel et al., 2020).

- Outputs from pyrolysis are not a directly recycled usable plastic. Further upgrade and processing is needed. As the pyrolysis oil is diluted with virgin naphtha to meet cracker standards, it means that only a very low fraction of chemically recycled material can be seen in the end product (Eunomia and CHEM Trust, 2020).

- Despite industry claims that chemical recycling can process various sorts of mixed plastic waste, relatively clean and homogenous plastic waste is required to achieve high yields and non-fuel based outputs (Eunomia and CHEM Trust, 2020).

Scope and Methodology

The findings presented below are based on a critical literature review of existing and commonly cited chemical recycling LCAs. The selected LCAs focus on pyrolysis, gasification, and solvolysis. Plastic-to-fuel LCAs have not been included in the scope, as the purpose is to review chemical recycling LCAs which claim to turn plastic back into plastic. However, similar concerns have in fact been observed in studies focused on plastic-to-fuel, particularly regarding the lack of data transparency, questionable GHG accounting methods, and misleading communication of results to policy-makers and the general public.[1]

[1] As an example, one such study (Benavides et al., 2017) comparing conventional fuel with plastic-derived fuels has been found to include emissions from combusting the former but not the latter, which is clearly biased (Rollinson and Tangri, 2020).

A list of the studies included in this review can be found below[2]:

List of LCA studies reviewed
Including abbreviated names used to refer to the studies in this paper

1. [BASF] Sphera Solutions GmbH, 2020, Evaluation of Pyrolysis with LCA - 3 case studies

2 [CE Delft*] Broeren, M., Lindgreen, E.R., Bergsma, G. 2018, Chemical Recycling Study. How great - what will be - the opportunities for climate policy? CE Delft

3. [Keller] Keller, F., Pin Lee, R., Meyer, B. 2020, Life cycle assessment of global warming potential, resource depletion and acidification potential of fossil, renewable and secondary feedstock for olefin production in Germany, Journal of Cleaner Production, 250, 119484, doi: 10.1016/j.jclepro.2019.119484

4. [Plastic Energy] Quantis, 2020: Life Cycle Assessment of plastic energy for the chemical recycling of mixed plastic waste. Prepared for Plastics Energy.

Critique of chemical recycling LCAs

1. **Claiming negative greenhouse gas emissions:** The BASF study shows that the greenhouse gas emissions from producing plastic (LDPE) via pyrolysis are approximately 77% higher than producing plastic using naphtha.[3] Yet, when the results of the study are summarised, it is claimed that pyrolysis is favourable to virgin plastic production and that it even has negative GHG emissions. This is explained by the attribution of 'avoided emissions' from alternative treatments for the plastic waste - in this case, from incinerating it (see Figure 1). This misleading presentation of climate impact fails to present the real GHG emissions data from the pyrolysis process technique itself in a transparent way.

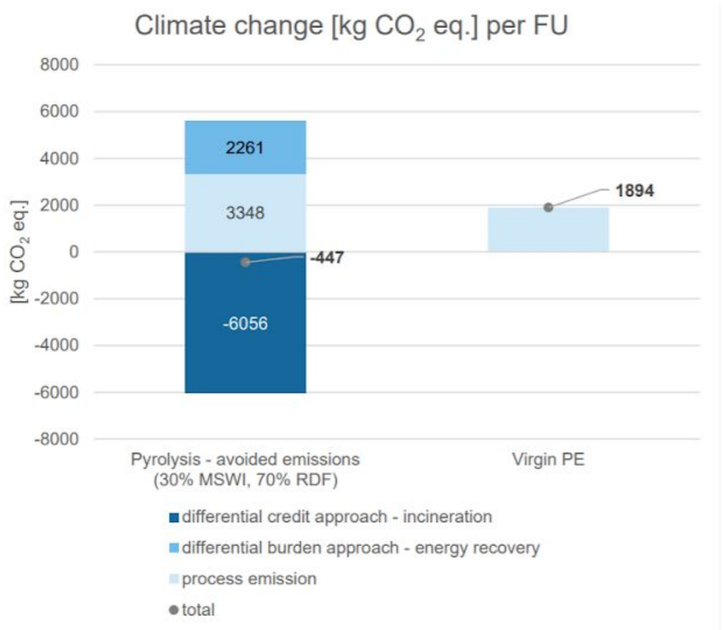

Figure 1 - BASF LCA and the use of "avoided emissions" to give climate credits to pyrolysis

[2] Please note the CE Delft study has a later revised 2019 document, available only in Dutch https://www.cedelft.eu/en/publications/2173/exploratory-study-on-chemical-recycling-update-2019. The Plastic Energy LCA critique is based on the summary document made available to the public: https://plasticenergy.com/wp-content/uploads/2020/10/Plastic-Energy-LCA-Executive-Summary.pdf

[3] 3,348 vs 1,894 CO_2 equivalents per functional unit (1 tonne of LDPE granulate produced in virgin-grade quality)

The practice of using discounted emissions from incineration and thereby assuming an ad infinitum recycling of polymers without degradation can be seen in several studies, including the BASF, CE Delft, Keller, and Plastic Energy studies. The LCA by Plastic Energy shows how GHG emissions from LDPE production via pyrolysis are higher than via mechanical recycling, as well as when compared to virgin LDPE production. Yet, it summarises the climate impacts for pyrolysis as being lower only due to avoided emissions from incineration (Figure 2).

Figure 2 - Plastic Energy LCA and the use of "avoided emissions"

The Keller study similarly shows how olefin production via gasification has approximately 7 times higher Global Warming Potential than production from virgin crude oil.[4] However, its final results still state that olefin production via plastic waste gasification is associated with significant greenhouse gas emissions benefits, thereby portraying again gasification as favourable through the attribution of 'avoided emissions' from incineration. This selective presentation of key findings results is a misleading view of the real climate impact of chemical recycling, and cannot therefore be used to make claims on the climate mitigation potential of this technology, or used as a basis for decision-making.

2. **Assuming pyrolysis requires little to no external energy:** Energy use of the chemical recycling process is generally the most important aspect to consider in an LCA, as it is the aspect that most influences both environmental and economic performance (Eunomia, 2020). In particular, pyrolysis is an energy-consuming endothermic process that requires substantial amounts of externally applied energy to raise reactor temperatures and maintain internal temperature stability (Rollinson and Oladejo, 2019; Patel et al., 2020). The industry, even via the BASF LCA, claims that the gas produced during pyrolysis of the plastic waste can be used to cover almost all of the energy required for the process. The company publicly claims that less than 1% of external energy input is needed for start-up processes[5]. However, the amount of gas produced in the process is not stated in the BASF study, nor is its projected calorific value.[6] There is a clear trade-off between the use of the pyrolysis products and by-products (pyrolysis oil, char, and gas) to make new products and their use for energy to feed the pyrolysis process itself. If the goal is to maximise yield (and future yield increase is another

[4] As shown in Figure 7 of the paper, chemical recycling has approximately 7 times higher GWP at ca. 12.5 kg CO_2 eq./kg olefin produced in comparison to that produced from virgin crude oil (value = 1.56 GWP) https://www.sciencedirect.com/science/article/pii/S0959652619343549
[5] See response under question 5: https://www.basf.com/global/en/who-we-are/sustainability/we-drive-sustainable-solutions/circular-economy/mass-balance-approach/chemcycling/FAQ_ChemCycling.html
[6] The study assumes a 71% carbon conversion efficiency in the most conservative scenario (based on confidential data) and a 87% yield in an imagined "future scenario" which assumes technology improvements. From the given mass flows and byproduct losses in the study, the total amount of gas available for energy supply would thus be, at a maximum, 19%.

assumed factor in the LCA), then there will be very little gas by-product left to run the process, which would then lead to further need for external energy input.

Regulatory analysis by Agilyx Tigard Plant (Patel et al., 2020) shows that combustion of 1 m3 of natural gas is needed for every kg of plastic processed by pyrolysis. As the full energy and mass balance data has not been provided, the BASF study does not adequately address the claim that the pyrolysis plant can be sufficiently supported by its own by-products while also producing high enough yields to make its outputs competitive with raw material for virgin plastic production. It is also worth noting that reported emissions from energy use in LCA studies are frequently based on extrapolated data, often with multiple assumptions.

In the CE Delft study, it is also not clear whether the authors have accounted for the energy costs of pyrolysis, as this part of the methodology is not stated. However, as the report claims that the hydrous pyrolysis technology 'does not cause direct emissions'[7], it is assumed that the real energy costs are not truly attributed, thereby falsely inflating the technology's environmental credentials. The Keller study is equally vague on the energy balance for chemical recycling and the inclusion of energy costs of all the post-processing systems, which would have a great impact on the GHG emissions. We demand transparent energy balances as proof and full disclosure of the energy demands of all process steps.

3. **Extrapolated and undisclosed datasets:** none of the studies fully discloses the datasets used. Hence, there is no possibility to reproduce the studies to verify their findings, which undermines their credibility. For the CE Delft study, the authors themselves state that, since many chemical recycling technologies are still in development and have not yet been implemented at industrial scale, there are uncertainties in the results and they should be considered as indicative.[8] For solvolysis, the study refers to data being obtained from a confidential source. In the BASF study, not even the reviewers were given access to the original data in order to evaluate its quality and comprehensiveness. In that study, only data from one single provider of pyrolysis oil was used and, despite the study being set within a German geographical boundary, the provider was located in Spain. The link between feedstock inputs and product outputs were thus hypothetical. Furthermore, the purification steps of pyrolysis outputs were based on primary lab-scale data, meaning the findings have merely been extrapolated to imagine a full-scale commercial scenario. This is unsuitable data for assessing pyrolysis, as the key technological difficulties lie in the transition from lab to semi-industrial scaling of operations (Rolinson and Oladejo, 2020).

   The Keller LCA is also vague on the parameters and assumptions made, including the assumption that the process is unaffected by the feedstock used. In reality, gasifiers are highly complex, involving multiple interconnected parameters and with feedstock composition having the most important influence on product quality (Rollinson and Oladejo, 2019). This unreliable and unsupported use of assumed and confidential data does not provide a strong basis for claims on environmental impacts of pyrolysis. If the data used to develop LCA studies cannot be communicated publicly, neither should their results.

4. **The use of future scenarios:** despite being unable to model a current scenario, considering the lack of large-scale pyrolysis plants to provide the data, the baseline for the BASF study is the anticipated situation in 2030 of the waste management and pyrolysis technology in Germany, as well as an anticipated 2030 national energy mix for the country.[9] The specific assumptions for the future scenario, as well as their impact on the results, are not fully presented in the study. This means the study results are largely based on unverifiable assumptions which are only valid as long as these assumptions are met in the future. Similarly, the CE Delft study has assumed large-scale applicability of the technologies while simultaneously revealing that 'some chemical technologies have sometimes been in development for decades, [and] it is unknown to what extent these are useable for current plastic flows'[10]. It should be noted that the use of future scenarios in chemical recycling LCAs has not taken into account a situation in which there are also improved conditions for

[7] CE Delft LCA, p.33
[8] Extended summary, p.4 https://www.cedelft.eu/en/publications/2173/exploratory-study-on-chemical-recycling-update-2019
[9] BASF LCA p.20
[10] Delft LCA p.6

mechanical recycling and waste prevention (see point 6). This has particular impact on studies which compare mechanical and chemical recycling, and suggests a biased use of future scenarios.

5. **Biased assumptions on alternative treatments of plastic waste**: through their comparative approach, all of the studies have assumed chemical recycling will replace incineration or energy recovery for plastic discards. This may be the current practice for plastic rejects in some parts of Germany and elsewhere, but it is not the case everywhere. Many countries - even within the EU - do not even have incinerators or have small capacities, and the circular economy agenda refrains them from investing into larger ones. In those areas, plastic rejects typically go to landfills, where carbon is sequestered. There are also companies that process low-grade plastic rejects through extrusion, which - under the scope of this document - may be considered equal to mechanical recycling. Furthermore, recent political developments[11] at the interface of waste and climate are moving plastics away from incineration, as this is becoming an outlier in the decarbonisation policy of the EU and member states.

   The EU Plastic Strategy mentions incineration as a large emitter of GHGs, and lately there have been public announcements in countries like Denmark and Belgium to reduce reliance on incinerators for plastic discards in order to to align with its agenda on decarbonisation[12]. These policies - coupled with the ambitions of the Single Use Plastic (SUP) Directive to promote Deposit Return Schemes (DRS), higher quality of collected plastic and, above all, phasing out of the hard-to-recycle plastics - will create a better enabling environment for waste prevention and mechanical recycling. The quantities of plastic packaging waste sent to recycling have almost doubled since 2006 (PlasticsEurope, 2019). Hence, assuming the availability of a consistent percentage of plastic discards from separate collection, and from sorting platforms which could be used as feedstock for "chemical recycling" or alternatively incineration, is a weak assumption of the studies which is not aligned with the EU circular economy agenda.

6. **Biased portrayal of mechanical recycling:** Mechanical recycling requires less energy input than chemical recycling (Levidow and Raman, 2019). Despite claims that chemical recycling will not compete with mechanical recycling waste streams, a comparison of climate impacts of the two processes has been made in various LCA studies, including BASF (chemical vs mechanical recycling of PE, PP, and PS) and Plastic Energy (chemical vs mechanical recycling of LDPE). In the BASF study, chemical recycling was compared with mechanical recycling despite the chosen waste fractions not being ideal for mechanical recycling prior to sorting, during which the rejects were sent for incineration[13]. It is important to highlight this fact when presenting the results of the study, as 90% of mechanical recycling emissions have been attributed to the incineration of rejects - a number that would have been far lower for a waste stream more suitable for mechanical recycling. Furthermore, the modelling assumed that by-products from the pyrolysis process are treated in cement kilns to replace lignite while discards from mechanical recycling process were treated through incineration. In fact, it is a common procedure in Europe to treat mechanical recycling residues in cement kilns as well. This different assumed treatment of by-products between the two processes has an impact on final results.

7. **Incomplete sensitivity analysis**: In the CE Delft study, the results do not provide any statistical analysis, nor do they offer any range values though they assess a range of technologies. Some of the results provide instead an absolute 'best case' outcome illustrating only 'the technology that scores best with respect to the environment'[14]. It is, thus, impossible to know whether the other chemical recycling technologies were comparable, worse, or far worse than incineration. In the BASF study, when adjusting different variables to see how they might affect the final emission results, key variables related to the pyrolysis process itself, such as the energy demand, have been ignored. As pyrolysis is a highly energy-intensive process, the amount of energy needed and its source have a substantial impact on the final emissions and climate impact. The variability of input waste quality was also not considered, although the study focuses on a waste fraction from one of the most modern sorting plants in Europe. In general, sensitivity analysis should not only focus on one impact category.

[11] Including the EU Sustainable Finance Taxonomy and the Just Transition Fund
[12]https://translate.google.de/translate?sl=da&tl=en&u=https%3A%2F%2Fmfvm.dk%2Fnyheder%2Fnyhed%2Fnyhed%2Fregeringen-vil-have-co2-regningen-for-affald-ned%2F
[13] BASF LCA p.95
[14] CE Delft LCA, p.29

8. **Selective presentation of results:** when compared to pyrolysis, incineration performed better in 10 out of 19 impact categories in the BASF LCA (such as acidification or eutrophication). Pyrolysis only outperformed incineration in 3 impact categories. Yet, communication efforts from the study focus mainly on one of these three impact categories: climate change. The communication of the results even goes as far as to make broad claims that 'chemically recycled plastics cause significantly lower CO2 emissions than those produced from primary fossil resources'[15] even though this is only in comparison with incineration, for only one plastic type (LDPE), in a German geographical context, and with a number of other assumptions made. The Keller study similarly found that the gasification route resulted in higher emissions of all airborne parameters (CO2, CO, dust, NOx, SO2), and had a higher acidification potential in comparison to virgin crude oil/shale gas olefin production. None of these findings were reflected in the abstract, which focused on portraying gasification favourably in the climate impact category by comparing it with incineration.

9. **Unknown purity and toxicity levels of outputs and processes**: toxicity indicators are frequently left out in LCAs and environmental impact studies of chemical recycling, although this impact category should be of high importance when assessing a new technique known to generate highly polluted waste streams. For example, gasification of plastic feedstock is associated with production of phthalates, BPA, polybrominated diphenyl ethers, toxic brominated compounds, and PAHs - many of which are mutagens, carcinogens, and disruptive to respiratory or neurological systems (Verma et al., 2016). Pyrolysis is also well known to create toxic organic products, and emission factors of mutagenic PAHs from polyethylene increase markedly with temperatures above 700°C (Rollinson and Oladejo, 2020). The CE Delft study excluded all environmental effects other than climate change, yet it claims its objective is to provide an understanding of the environmental performance of chemical recycling technologies to help 'guide policymakers in policy choices'.[16] Similarly, the Plastic Energy study only focused on climate and resource use indicators. In the study commissioned by BASF, toxicity results were described as having a high uncertainty. Furthermore, material composition, toxicity, and fate of waste streams remain unclear for several processes such as pyrolysis, purification, and steam cracking. Therefore, no reliable data on human toxicity and ecotoxicity impacts from chemical recycling processes have been made available.

10. **Claiming virgin quality outputs:** the BASF study assumes that the pyrolysis process can eventually lead to plastic products with a quality comparable to virgin plastic. The CE Delft study also assumes that chemical recycling products can be sold and are of sufficient quality to replace conventional plastic production. However, numerous studies have found that pyrolysis oil from plastic waste has very high levels of toxic pollutants (Rollinson and Oladejo, 2020) and, thus, only a very low proportion of pyrolysis oil can currently be fed into existing cracking processes (Eunomia and CHEM Trust, 2020). There are two possible solutions to this problem. One is to purify and upgrade the pyrolysis oil until it meets the cracker specifications. However, this process is energy-intensive, carbon-intensive, and low-yield (Seidl et al., 2020; Mamani-Soliz et al., 2020). The other option is to dilute a small amount of pyrolysis oil with a much larger quantity of virgin fossil feedstock. This will sufficiently reduce the total contamination to allow production. However, this also means that the amount of recycled content in the new plastic is so low that it can hardly be considered recycling. It may be possible that running an equivalent cracking process using only pyrolysis oil is not even technically feasible. If a certain proportion of naphtha is necessary to run the process, environmental impacts from this fossil-based material must be included in the LCA as well. Moreover, it still remains unclear whether emission data, energy requirements, and quality demands of pyrolysis oil inputs are still valid for high shares of pyrolysis oil in the cracker input.

[15]https://www.basf.com/global/en/who-we-are/sustainability/we-drive-sustainable-solutions/circular-economy/mass-balance-approach/chemcycling/lca-for-chemcycling.html
[16] CE Delft LCA p.44

Conclusions and Recommendations

It is very easy for results of LCA studies to be misinterpreted. This review has revealed ten ways in which existing chemical recycling LCAs are using undisclosed datasets, flawed assumptions, and creative accounting methods to provide misleading information on the climate and environmental impacts of the technologies.

Businesses have shown a tendency to report the main findings of LCAs without providing the full context. LCAs are often conducted within a narrow geographical boundary, with the energy mix of that country, on a specific waste fraction, and using assumptions which, using other variables, would have provided vastly different results. Yet, the results are communicated broadly without full disclosure of the circumstances, giving the illusion that decisive conclusions may be drawn from the study.

If the data used to develop LCA studies cannot be publicly communicated , neither should their results.

As such, chemical recycling LCAs should not be used for public communication or as a basis for decision-making or investments, but rather as a tool to support wider discussions.[17] **We strongly recommend policy-makers to take a precautionary approach** when interpreting environmental and climate impacts of chemical recycling-based on LCAs given the critical findings of this review.

Finally, we call for the development of more independent, transparent, and comprehensive assessments of environmental and climate impacts of chemical recycling based on primary data sources prior to developing further legislative frameworks incentivising these technologies.[18]

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Zero Waste Europe is the European network of communities, local leaders, businesses, experts, and change agents working towards the same vision: phasing out waste from our society. We empower communities to redesign their relationship with resources, to adopt smarter lifestyles and sustainable consumption patterns, and to think circular.

The EEB is the largest network of environmental citizens' organisations in Europe. It currently consists of over 160 member organisations in more than 35 countries (all EU Member States plus some accession and neighbouring countries), including a growing number of European networks, and representing some 30 million individual members and supporters.

Environmental Action Germany (DUH) has been campaigning to preserve the natural foundations of life for more than 40 years. In doing so, it brings together protecting the environment with consumer protection like no other organisation in Germany.

ECOS is an environmental NGO with a network of members and experts advocating for environmentally ambitious technical standards, policies, and laws. We ensure the environmental voice is heard at the table where these standards, policies, and laws are developed, challenging policymakers and industry players to implement strong environmental principles.

GAIA is a worldwide alliance of more than 800 grassroots groups, non-governmental organizations, and individuals in over 90 countries. With our work we aim to catalyze a global shift towards environmental justice by strengthening grassroots social movements that advance solutions to waste and pollution. We envision a just, zero waste world built on respect for ecological limits and community rights, where people are free from the burden of toxic pollution, and resources are sustainably conserved, not burned or dumped.

Rethink Plastic, part of the Break Free From Plastic movement, is an alliance of leading European NGOs working towards ambitious EU policies on plastics. It brings together the Center for International Environmental Law (CIEL), ClientEarth, Environmental Investigation Agency (EIA), European Environmental Bureau (EEB), European Environmental Citizen's Organisation for Standardisation (ECOS), Greenpeace, Seas At Risk, Surfrider Foundation Europe, and Zero Waste Europe. Together they represent thousands of active groups, supporters and citizens in every EU Member State working towards a future free from plastic pollution.

Founded in 1899, NABU (Nature And Biodiversity Conservation Union), is one of the oldest and largest environment associations in Germany. The association encompasses more than 770,000 members and sponsors, who commit themselves to the conservation of threatened habitats, flora and fauna, to climate protection and energy policy. NABU's main objectives are the preservation of habitats and biodiversity, the promotion of sustainability in agriculture, forest management and water supply and distribution, as well as to enhance the significance of nature onservation in our society.

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WEST COAST OLEFINS LTD.

West Coast Olefins Project

Preliminary Project Description

September 12, 2019

Revision 1

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List of Tables

List of Figures

List of Acronyms and Abbreviations

Acronym / Abbreviation	Definition
AM	Accidents and Malfunctions, specific to Tables 2.7, 2.8 and 2.10
ALR	Agricultural Land Reserve
BC	British Columbia
BCEAA	BC Environmental Assessment Act
BC EAO	BC Environmental Assessment Office
BC OGC	British Columbia Oil and Gas Commission
BEP	Basic Engineering Package
C	construction phase, specific to Tables 2.7, 2.8 and 2.10
C2+	hydrocarbons with 2 or more carbon atoms in the carbon chain
C3	hydrocarbons with 3-carbon chains
C4	hydrocarbons with 4-carbon chains
C4+	hydrocarbons with 4 or more carbon atoms in the carbon chain
C5+	hydrocarbons with 5 or more carbon atoms in the carbon chain
Cdn	Canadian dollars
CEAA	Canadian Environmental Assessment Act
CNC	College of New Caledonia
CO_2	carbon dioxide
D	decommissioning phase, specific to Tables 2.7, 2.8 and 2.10
FID	Final Investment Decision
GHG	greenhouse gas
H_2S	hydrogen sulphide
IFD	Issued For Design
LHA	Local Health Area
NGL	natural gas liquid
NO_2	nitrogen dioxide
NOx	any of several possible nitrogen oxides
O	operation phase, specific to Tables 2.7, 2.8 and 2.10
PM	particulate matter
$PM_{2.5}$	particulate matter with particle diameters less than 2.5 micrometres
PM_{10}	particulate matter with particle diameters less than 10 micrometres

Acronym / Abbreviation	Definition
RAAD	Remote Access to Archaeological Data
RDFFG	Regional District of Fraser-Fort George
SBS	Sub-boreal Spruce
SOx	any of several possible sulphur oxides
UNBC	University of Northern British Columba
USGC	USA Gulf Coast
VHP	very high pressure
VOC	volatile organic compound(s)

List of Symbols and Units of Measure

Symbol / Unit of Measure	Definition
%	percent
<	less than
>	greater than
Btu	British thermal unit
°C	degrees Celsius
GJ/h	gigajoules per hour
km	kilometre
kPag	kiloPascals gauge pressure
kV	kilovolts
lb	pound
m	metre
mm	milimetre
m^3/d	cubic metres per day
m^3/h	cubic metres per hour
M	million
Mt/y	millions of tonnes per year
MW	megawatts
pH	a measure of acidity
Sm^3/d	standard cubic metres per day
t/d	tonnes per day
t/h	tonnes per hour

t/y	tonnes per year
µm	micrometre (one-millionth of one metre)

Defined Terms

Term	Description
Application	Application for an Environmental Assessment Certificate
Extraction Site	the location of the NGL Extraction Plant
Riparian	interface between land and body of water
NGL Recovery Plant	Separately owned WCOL subsidiary, comprised of two separately sited component Plants: The NGL Extraction Plant, and the NGL Separation Plant. The NGL Extraction Plant will be located at the Extraction Site. The NGL Separation Plant will be located in the Project Area.
NGL Extraction Plant	Individual Plant, but part of the NGL Recovery Plant. Located on the Extraction Site. Receives rich gas from the Westcoast Pipeline, removing a mixture of NGLs (ethane and heavier) and returning a leaner natural gas to the pipeline.
NGL Separation Plant	Individual Plant, but part of the NGL Recovery Plant. Located within the Project Area. Will receive C2+ NGL from the NGL Extraction Plant, and separate into 4 products: ethane, propane, butane and condensate.
Ethylene Project	Subject of this EA Project Description. Will receive ethane feedstock from NGL Separation Plant and convert it into ethylene product. Also referred to as "the Project". Consists of Ethylene Plant and all associated utilities and infrastructure.
Ethylene Derivative Plant	A separate plant owned by a third party partner. Receives ethylene product from the Ethylene Plant and converts it into polyethylene, and potentially mono-ethylene glycol, product.
Project Area	Site of the Ethylene Plant. Located within the BCR Industrial Area. NGL Separation Plant will also be located on this site.
Fired CO2	CO2 that results due to combustion
Unfired/Process CO2	CO2 that results due to chemical removal processes (amine treatment) and is removed from the Westcoast Pipeline natural gas.

1 Introduction

West Coast Olefins Ltd. (WCOL), through a wholly owned subsidiary, is proposing to develop the West Coast Olefins Ethylene Project (Ethylene Project, or Project) that will convert ethane to produce polymer-grade ethylene. The Ethylene Project will be located within existing industrial lands in the City of Prince George, British Columbia (BC). The Project will produce and sell approximately 1 million tonnes per year (Mt/y) of polymer-grade ethylene and will have an initial lifespan of approximately 25 years.

The ethane will be purchased from a Natural Gas Liquid (NGL) Recovery Plant owned by a separate subsidiary of WCOL, which will recover the ethane and other NGLs from the Enbridge Westcoast Pipeline that runs just east of Prince George. The ethane purchased from the NGL Recovery Plant will be used by the Ethylene Project as a feedstock to produce ethylene. The recovered ethylene will be sold to an Ethylene Derivative Plant, owned by a third-party company, that will produce derivative products such as polyethylene or mono-ethylene glycol. The relationship of the Ethylene Project and the NGL Recovery and Derivative Plants is represented in Figure 1.1.

The WCOL team anticipates the Project will be subject to review under the BC *Environmental Assessment Act* (BCEAA), SBC 2002, c. 43 (see Section 1.5 for details). The purpose of this Project Description is to:

- Provide an overview of Project information to enable the BC Environmental Assessment Office (BC EAO) to determine whether an Environmental Assessment (EA) is required under the enabling legislation.
- Provide other parties and stakeholders (e.g., provincial government agencies, Indigenous groups, local and regional governments, the public) with information about the Project so that they can determine whether they have an interest that would be affected by the Project.
- Provide an overview of other facilities related to the ethylene supply chain, which will be developed in parallel to the Project, but which are not part of this Project Description or the EA for the Project. This will provide stakeholders with additional context to be considered in evaluating cumulative impacts.

The Project Description has been prepared in accordance with *Preparing a Project Description for an Environmental Assessment in British Columbia* (BC Environmental Assessment Office , 2016).

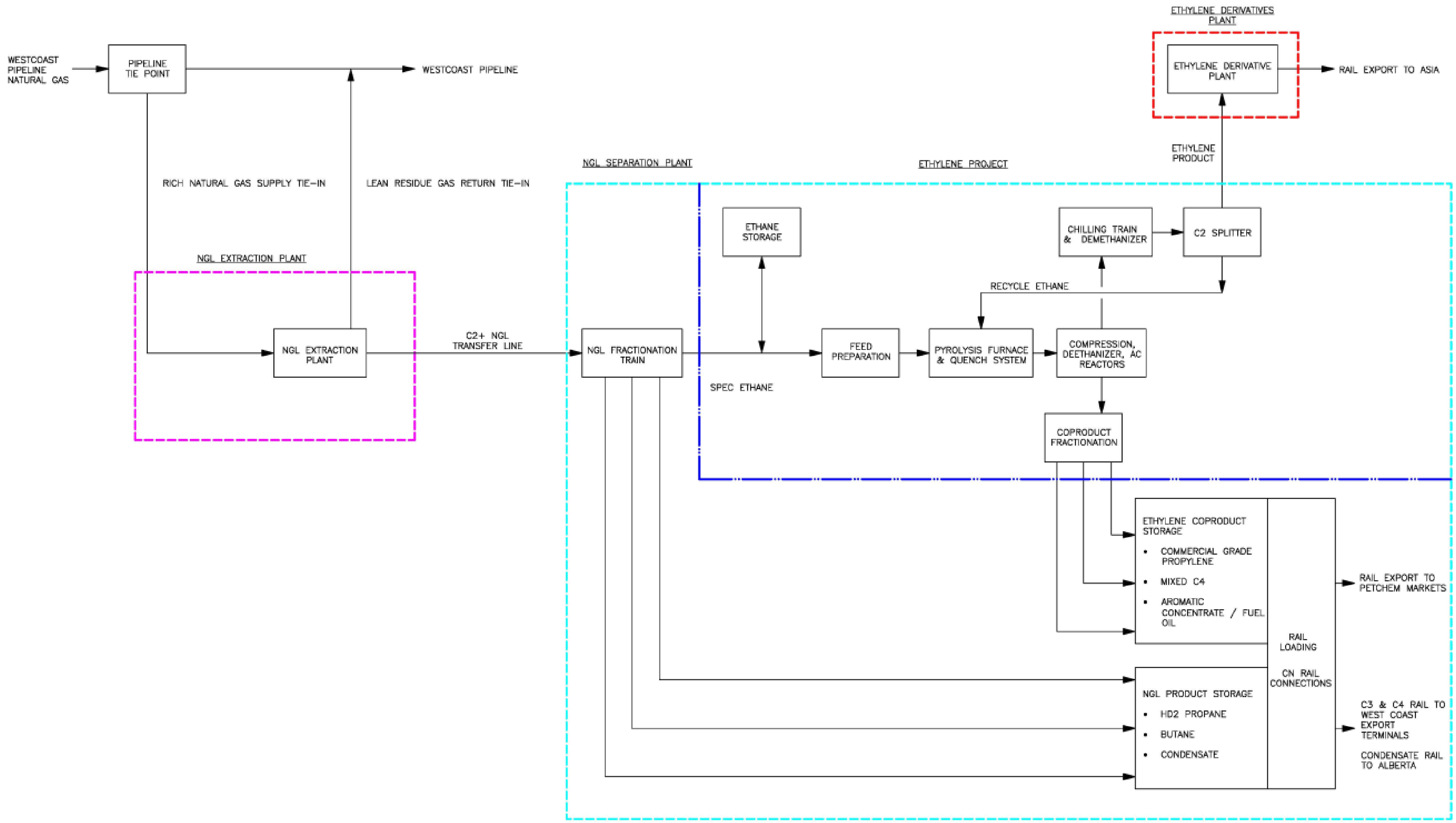

Figure 1.1: Ethylene Project's Relation to NGL Recovery Plant and Ethylene Derivative Plant

1.1 Project Overview

The Project will purchase ethane from the NGL Recovery Plant. The ethane feedstock will be processed to remove contaminants such as carbon dioxide (CO_2) and hydrogen sulphide (H_2S) and then converted to ethylene and a mixture of other products in Pyrolysis Furnaces. Undesirable contaminants will be removed, and the primary ethylene product will be separated from the other byproducts. The ethylene will be sold to the Ethylene Derivatives Plant and the other byproducts sent to the NGL Recovery Plant to be loaded onto rail cars for delivery to markets in Canada and the USA.

The Project is proposed to be located on over 120 hectares of previously developed, fee simple land located within an industrial zone in the City of Prince George. WCOL has selected Prince George as the location of the Project because of the superior combination of existing infrastructure and resources (e.g., rail, power infrastructure, existing pipeline access, Fraser River) and the stable and sizable population base. The site location has been selected to minimize the use of undisturbed land, thereby minimizing potential environmental impacts from the facility location. See Figure 1.2 and Section 3.

The Project development is currently in the conceptual stage and is proceeding to the Basic Engineering Package (BEP) phase through the remainder of 2019 and into early 2020. Design information from the BEP phase will be incorporated into the Application for an Environmental Assessment Certificate (Application) for the Project to BC EAO. Many options relative to the design and execution of the Project will be assessed and developed during the BEP phase. Current concepts are described in Section 2; as the details related to the Project are developed, the updated options and designs will be presented in the Application.

The Issued for Design (IFD) engineering stage is planned for completion in 2020, which supports a targeted final investment decision (FID) by the fourth quarter of 2020. Assuming regulatory approvals leading to a positive FID, fabrication and construction activities will start in early 2021, and plant start-up is planned to occur by the end of 2023.

1.1.1 Project Rationale

The Project is an Ethylene Plant, which will utilize low-cost, abundant ethane from natural gas production primarily in northeastern BC and generate ethylene that can be further manufactured into derivative products such as polyethylene and mono-ethylene glycol, for export to growing Asian markets. The Project will utilize ethane that is available from the existing Westcoast Pipeline, thereby adding value to a resource that has been under-utilized for decades, while avoiding the need for the construction of any new major pipelines. The Project is part of an ethylene value chain, and 2 other facilities will be developed outside the Project, but on roughly the same schedule: an NGL Recovery Plant and an Ethylene Derivative Plant. The NGL Recovery Plant will undergo a BC Oil and Gas Commission (OGC) application, and the Ethylene Derivative Plant will undergo a separate EA process. See Section 1.2.1 for further information on the ethylene value chain and facilities not covered by this Project Description.

1.1.2 Project Benefits

The Project will create tremendous value-added economic benefits from a natural gas resource that is otherwise destined to be burned as fuel by customers on the Westcoast Pipeline system. Close to a $1 million per day of value will be created through the conversion of ethane to ethylene in the ethylene value chain, and additional revenue of a similar magnitude will be realized from the other facilities in the extended ethylene value chain. The $2.0 billion to $2.8 billion Project will generate thousands of person-years of employment during the construction period and up to 230 permanent, direct and contract employment positions once the Project reaches commercial operation. Once the plants are in operation, approximately $20 million to $50 million will be needed per year of sustaining capital investment, which will in turn generate significant on-going economic benefits to the local community. Numerous other indirect benefits will accrue to the local community, such as training at local institutions (University of Northern British Columbia and College of New Caledonia (UNBC and CNC)), support services (i.e. transport, food, lodging, maintenance, professional services, etc.) and associated new business development opportunities.

Ethane, as a feedstock, is the most direct, lowest energy route to manufacturing ethylene, giving the Project an environmental edge over ethylene plants based on hydrocarbon liquids or coal as a feedstock. The Project will utilize latest technology in the design of the Ethylene Plant, such as highly energy efficient plant designs, the use of ultra-low NOx (nitrogen oxide) burners and the use of clean burning fuel to reduce greenhouse gas (GHG) emissions. The combination of feedstock and new plant design will make the Plant a low emissions facility from a local perspective and “best-in-class” relative to other facilities globally.

The Ethylene Plant will be designed and operated to minimize the impacts on water sources and aquatic life. The Project will be located on fee simple land in an existing and under-utilized industrial park within the city limits of Prince George to minimize land disturbance.

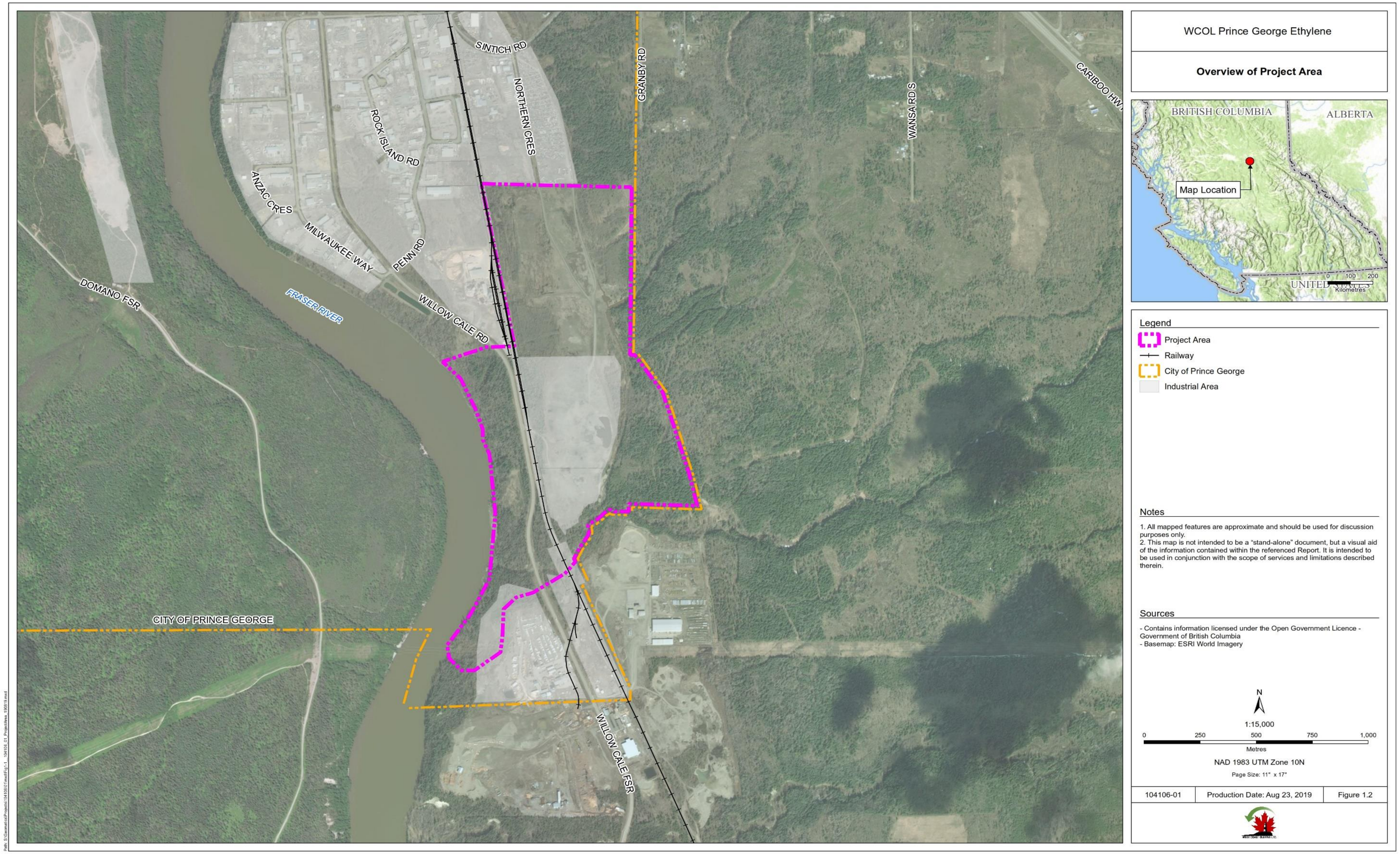

Figure 1.2: WCOL Project Area Location.

1.2 Scope of Related Ethylene Value Chain

As noted in Section 1, the Project will convert purchased ethane into ethylene, for sale to a third-party who will produce ethylene derivative products. The various facilities involved in this transformation, including the proposed Project, comprise the ethylene value chain and will include:

- An NGL Recovery Plant to recover ethane, propane, butane and natural gas condensate from Enbridge's Westcoast Pipeline.
- The Ethylene Plant Project, which will produce nominally 1 Mt/y of polymer-grade ethylene.
- A Polyethylene Plant developed by others to consume the majority (70% to100%) of ethylene produced and potential for a future Mono-ethylene Glycol Plant to be developed by others to utilize the balance of the ethylene produced. Collectively, these facilities will be referred to as the Ethylene Derivative Plant (or Derivative Plant). The ethylene derivative products are used in the manufacture of plastic products, fabrics, etc.

This Project Description specifically pertains to the EA process for the Ethylene Project, which consists of the Ethylene Plant and directly related utilities and infrastructure. Separate regulatory applications are being submitted for other facets of the ethylene supply chain. The purpose of Section 1.2 is to provide a clear explanation of the regulatory and business rationale for the separate applications as well as an explanation of how regulatory applications for all aspects of the development will be managed.

This is a new industry in BC, one that offers considerable value, both in generating revenue from otherwise under-utilized natural gas liquids and reducing the carbon footprint of Canada's natural gas industry by returning a leaner, clean burning natural gas to the Westcoast Pipeline. Unlike in other locations where a mature industry exists for ethylene recovery and use (such as the US Gulf Coast), established business interests do not yet exist in BC for each of the key components in the value chain. For instance, there are no consumers of ethane or ethylene within BC. A value chain is a series of related businesses which extract value from a particular commodity (in this case ethylene) by converting it into other value added products. Thus, at this early juncture, and to grow the industry, WCOL will be the catalyst for and partially involved in several components that in the future will be independently owned and operated businesses.

This development has been designed to accommodate the need for a separate regulatory review process for each of the 3 key components, which would result in a separate and individually transferable suite of approval conditions for each. This approach acknowledges that until a mature industry develops, the multitude of possible end uses resulting from ethylene production cannot be predicted, and the independence of each is critical, as described further in this section. Each component in the overall value chain will be subject to a regulatory approval process, either by the BC EAO or by the BC OGC, with the cumulative effect of the overall development being outlined in the EA Application for the Ethylene Project (see Section 1.2.3). This arrangement provides for a robust and appropriate assessment for each component, and where applicable, acknowledges the need to address the combined or cumulative influence of the overall supply chain.

1.2.1 Business Structure

The WCOL Ethylene Plant will have a unique but not exclusive business relationship with the NGL Recovery Plant and the Ethylene Derivative Plant Each of these 3 facilities is expected to have separate ownership as the projects move forward and hence the need for each business to file separate regulatory applications (see Section 1.2.3) to construct new facilities in the Prince George region. During the regulatory and permitting process there is the need for separate permits for these facilities while ensuring that the aggregate environmental impacts are evaluated. WCOL's intent is to include a detailed evaluation of the social, economic and environmental impacts of the Ethylene Plant as well as an overview of the overall impacts for the combined project.

The NGL Recovery Plant will extract the ethane, propane, butane and natural gas condensate from Enbridge's Westcoast Pipeline that runs just east of Prince George. This facility will process natural gas as a service to upstream natural gas producers, who will sell these liquid products at much higher value in the market. The propane and butane will serve local markets and be exported into international markets via ports on the west coast of British Columbia. The condensate product would be an ideal local source of feed to be refined in the Prince George refinery or could be exported to Alberta.

Ethane is the one product that does not have a readily available market in BC, and this is the rationale for the WCOL Ethylene Plant, which will be the sole purchaser of ethane recovered from the NGL Recovery Plant on a long-term (25 year), take-or-pay basis. They will be 2 distinct and independent companies with different ownership and management. The source for ethane will likely change over time as more ethane becomes available from pipelines supplying various liquefied natural gas plants that are currently in various stages of development. This prediction is consistent with what happened in Joffre, Alberta, where the ethane supply was originally provided by the Alberta Ethane Gathering System but now includes ethane from North Dakota, oilsands off-gases and ethane extracted from the natural gas feed to the cogeneration system at the plant site.

WCOL plans to operate the Ethylene Plant as a midstream service between the seller of the ethane feedstock (the NGL Recovery Plant) and the buyer of the ethylene (the Derivative Plant) produced in the plant. Ethylene will be sold to the Derivative Plant on a cost-of-service basis via a long-term purchase agreement, and the owner of the Derivative Plant will then design, construct and operate the facilities that will convert the ethylene into polyethylene or other derivatives such as mono-ethylene glycol. The Ethylene Plant and Derivative Plant need to proceed on same construction schedule, as the only consumer of the ethylene product from the Ethylene Plant will be the Derivative Plant. The Derivative Plant proponent will seek separate EA approval for this project.

Once the plants reach full commercial operation, numerous scenarios could result in the 3 plants operating independently of each other. For example, if an event causes an outage or delay in the initial start-up in either the Ethylene Plant or Ethylene Derivative Plant, the NGL Recovery Plant would continue to operate in ethane rejection mode but would recover propane, butane and natural gas condensate.

In addition to the business rationale for separate permitting processes for each of the 3 projects, other issues need to be considered over the life of the operations:

- Proceeding with a single regulatory approval and permitting application for the 3 projects would require that all parties provide required information to prepare and respond to requests generated through the regulatory process. This would be particularly difficult where proprietary technology or market information is involved.
- Post start-up, operating the plants under a single permit would be difficult as it would require that all parties make the necessary information available to meet regulatory reporting requirements. This would become very complex when each company is required to consider the division of environmental liabilities should an incident occur.
- It is very likely that the future relationship between the NGL Recovery Plant, the Ethylene Plant and the Ethylene Derivative Plant will change at some point in the future, making a combined permit impractical. This has certainly proven to be the case for the Alberta ethylene plants, for which, as noted above, the source of feedstock has expanded dramatically The original ethylene buyers have also changed over time, for example, Dow started as the only buyer of the ethylene from the first ethylene plant, but no longer purchases ethylene from the original Nova Chemicals ethylene plant.

The three related projects have been defined to align with the different business ownership models and separate regulatory applications will be filed for each, as described in Section 1.2.3.

1.2.2 Elements in the Ethylene Supply Chain

Through discussions between WCOL, BC EAO, and BC OGC, a regulatory approval process has been designed to (i) ensure appropriate and rigorous evaluation of the impacts of the overall development **and** (ii) divide the overall development into 3 component pieces: the NGL Recovery Plant, the Ethylene Plant and the Ethylene Derivative Plant. Each of the components in the supply chain is a major processing facility with unique regulatory needs and business considerations.

Ethylene Project

The Ethylene Project is the subject of this EA Project Description, and the facilities and operation for this Project are described in detail in the balance of this document. The Ethylene Project will be located on a site in Prince George's industrial park, referred to as the Project Area (see Section 3). The Project will purchase ethane feedstock from the NGL Separation Plant and primarily convert it into ethylene product (roughly 80% of the total production from the facility), with the remainder being hydrogen-rich offgas and some mixed liquid coproducts. The ethylene product will be sold to the Ethylene Derivative Plant. Offgas will be recycled as fuel within the Ethylene Project; its hydrogen-rich nature will reduce GHG emissions that might otherwise be associated with the facility if other fuels were used instead. Liquid coproducts, consisting of mixed C3, mixed C4, aromatic concentrate and pyrolysis fuel oil, will be sent to the storage and rail loading facilities owned and operated by the NGL Separation Plant proponent, then loaded onto rail cars and likely sent to Alberta or the USA Gulf Coast (USGC) where they typically become feed streams for other petrochemical or refinery facilities.

NGL Recovery Plant

The purpose of the NGL Recovery Plant is to recover an NGL mixture of ethane, propane, butane and condensate (C2+) from the Westcoast Pipeline and then separate this mixture of NGL into separate product streams (e.g. ethane, propane, etc.). There are 2 separately sited component facilities in the NGL Recovery Plant:

1. The NGL Extraction Plant will process rich natural gas from Enbridge's Westcoast Pipeline, removing a mixture of otherwise under-utilized NGLs (ethane, propane, butane and condensates) and returning a leaner and cleaner-burning natural gas to the pipeline for export or domestic use. The NGL mixture will be sent from the NGL Extraction Plant via an underground Transfer Line to the NGL Separation Plant. The NGL Extraction Plant will be located at a site adjacent to the Westcoast Pipeline, less than 10 km from Prince George.
2. The NGL Separation Plant will separate the 4 mixed NGL products received from the Extraction Plant: ethane, propane, butane and condensate. The ethane will be sent to the Ethylene Plant Project as feedstock. The propane and butane will be loaded on rail cars and likely sent to third-party Liquefied Petroleum Gas (LPG) marine export terminals in Prince Rupert or Kitimat for export to Asia. Expected product volumes will result in the movement of a full Unit Train of rail cars roughly every other day. The condensate will be loaded onto rail cars and sent to Alberta for sale into the condensate pool, or it could be sold as feedstock to the Husky refinery in Prince George. The NGL Separation Plant will be

located adjacent to, but separate from, the Ethylene Plant in the Project Area site.

Additional detail related to the scope of the NGL Recovery Plant and its component facilities is contained in Appendix B.

Ethylene Derivative Plant

The Ethylene Derivative Plant will purchase ethylene product from the Ethylene Project and convert it into polyethylene product, most likely in the form of polyethylene pellets, for shipment to the growing Asian market. The capacity of this facility is nominally 1 Mt/y of polyethylene product, with no coproducts produced. Facilities associated with the Derivative Plant are expected to be located within the Prince George industrial corridor and could be co-located at the Ethylene Project Area. Polyethylene product will be loaded into rail cars at the Ethylene Derivative Plant, resulting in the movement of a full Unit Train of rail cars roughly every 2 or 3 days.

This part of the Project will likely be developed by an international partner with a global share of the polyethylene market. They will select the technology and process design of the facility to meet future demands of the polyethylene market. Until this partner is selected, the scope and design of the Ethylene Derivative Plant cannot be defined as the equipment can vary substantially depending on the slate of products and the fundamental technology choices of the future developer.

Some of the derivatives partner(s) currently being considered by WCOL would potentially divide the derivatives production and build a Mono-ethylene Glycol Plant to consume some of the ethylene. This product would also be destined for export to the Asian market.

1.2.3 Regulatory Strategy

WCOL and the Ethylene Project are the catalyst for the overall ethylene supply chain development. Each of the components of the initiative will submit separate regulatory applications as follows:

- The EA covered within this Project Description is being submitted for the Ethylene Project, which includes the Ethylene Plant and all associated utilities, infrastructure and off-sites scope, with assets located at the Project Area site.
- An OGC application will be submitted for the NGL Recovery Plant, covering the NGL Extraction and NGL Separation plants and all associated utilities, infrastructure and off-site scope, with assets located both at and between the NGL Extraction Site at the Westcoast Pipeline and the Project Area site.
- A future and separate EA Application will be submitted for the Ethylene Derivatives Plant, which may include a Ethylene Derivative Plant or other

ethylene derivatives, and all associated utilities, infrastructure and off-sites scope. The site location and the proponent have not yet been selected.

WCOL has developed a regulatory strategy that will consider cumulative impacts of the total development, while filing the 3 separate applications. The proposed regulatory application approach is discussed in the following sub-sections and depicted in Figure 1.3.

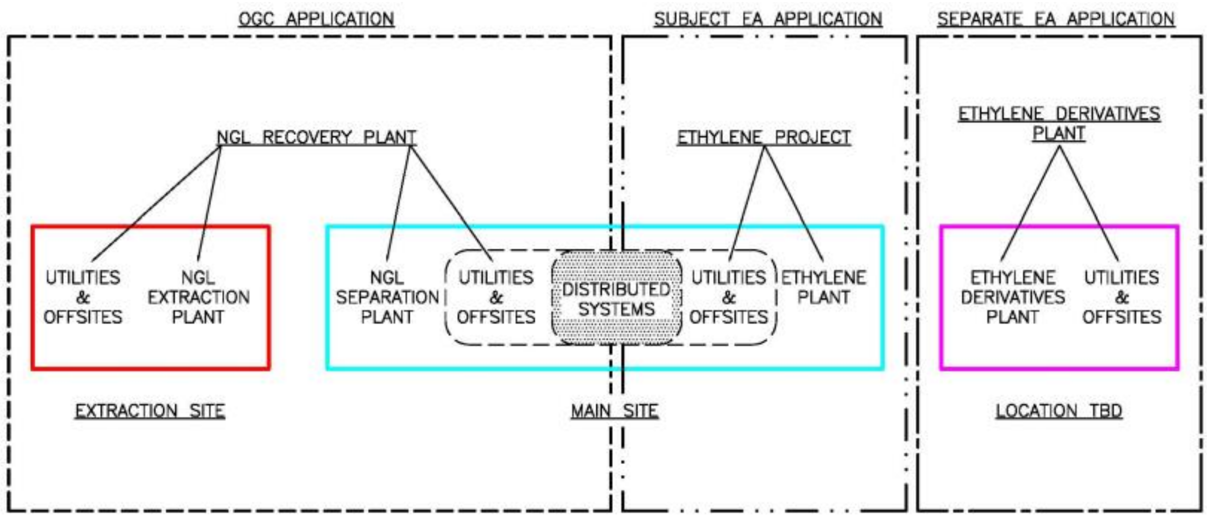

Figure 1.3: Depiction of WCOL Development Application Approach.

Ethylene Project

WCOL will submit an EA Application for the Ethylene Project, as described in this Project Description. As required by the BC OGC, WCOL will also initiate an application process for the separate approval requirements required of the Ethylene Project.

NGL Recovery Plant

The NGL Recovery Plant will be the subject of a BC OGC application, with an expected filing date during the first half of 2020.

This BC OGC application will cover:

- All impacts associated with the NGL Extraction Plant, mixed NGL storage and utilities or infrastructure at the pipeline Extraction Site
- The NGL Transfer Line from the Extraction Site to the Ethylene Plant Project Area at the Prince George Industrial Park
- All impacts associated with the NGL Separation Plant, liquid hydrocarbon storage, rail loading facilities and dedicated utilities at the Prince George Industrial Park

Water usage or disposal requirements for this plant are minor, and the intention is to provide water requirements on a fee-for-service basis from the Ethylene Project. Consequently, the NGL Recovery Plant is not expected to require its own water withdrawal or water discharge licence. Stormwater management at the Prince George Industrial Park site will be required, but the management strategy will be dependent on the site layout: the NGL Separation Plant might have an independent stormwater collection and management system, or there might be a single system for the site, which would be included in the design and Application for the Ethylene Project.

WCOL will perform cumulative effects assessments on applicable past, present and reasonably foreseeable projects and related Plant components within the agreed study area boundaries (NGL Recovery Plant, Ethylene Plant, and Ethylene Derivitives Plant, as appropriate).

Ethylene Derivative Plant

The Ethylene Derivative Plant is an component of the overall supply chain that will complete a separate EA Application. The development and submission of this EA Application will be the responsibility of the third-party ethylene derivative partner. This EA Application is expected to lag behind the Ethylene Project EA Application by 6 to 9 months.

See Section above for how cumulative effects assessments will be carried out.

Following early discussions with regulators, the Ethylene Derivative Plant may not fall under the mandate of the BC OGC, and any required water or air emissions permits might be issued by the BC Ministry of Environment and Climate Change Strategy. These details will need to be resolved once the ethylene derivatives owner engages with regulator(s).

1.3 Proponent Information

The Project will be developed by a subsidiary of WCOL, a private Canadian company that is developing value-added petrochemical projects to access abundant feedstocks available in western Canada.

WCOL and the Project will proceed/operate under the following corporate policies:

- **Provision of environmental benefits**: WCOL is taking measures to reduce our carbon footprint during the operation phase of the Project. Some of the environmental benefits include the use of the latest technologies for an energy-efficient design of the Ethylene Plant process, use of low emission fuel gas for the Pyrolysis Furnaces, use of ultra-low NOx burners and maximization of water re-use and recycling.
- **Provision of long-term local benefits**: The Project is anticipated to foster diversification of the local economy; generation of long-term, highly skilled job

positions during the construction and operation phase of the plant; indirect economic benefits to the local community; training and skills upgrading at local institutions; opportunities to provide support services; and new associated business development opportunities.

- **Best-in-class technology and operating standards**: The Ethylene Plant will be operated with processes and procedures that ensure reliable and optimized plant operation (high thermal efficiencies, high product yield), reduce safety incidents, and meet regulatory targets.
- **Consultation with Indigenous People, stakeholders and regulatory agencies**: WCOL recognizes that the Project has the potential to directly interact with the rights, interests, uses and activities of the community and understands that open dialogue and community engagement will be important throughout the Project's development.
- **Competitive access to markets**: Due to the location of the Ethylene Project, this Project has structural advantages over key competitors, and this positions the proposed facilities to be a low-cost global producer.
- **Health and safety**: WCOL understands the crucial need for safe practices and procedures. Precautions such as rigorous training programs and access to medical and emergency systems will be employed.

WCOL information and key contacts are listed in Table 1.1.

Table 1.1: Proponent Information and Key Contacts.

Project Name	West Coast Olefins Ethylene Project
Proponent Name	West Coast Olefins Limited
Proponent Corporate Address	555 - 4 Ave. SW, Suite 1700 Calgary, AB, Canada T2P 3E7
Proponent Contact Information	Email: info@westcoastolefins.com Phone: 403-350-8434
Company Website	https://www.westcoastolefins.com/
Company President	Ken James
Principal Contact Person for West Coast Olefins Ethylene Project	Ron Just Chief Operating Officer rjust@westcoastolefins.com 403-350-8434

1.4 Consultation with Indigenous Groups, Stakeholders and Regulatory Agencies

WCOL values the importance of engagement with Indigenous groups, community stakeholders, and regulatory bodies potentially affected by the Project. WCOL views the support of these groups as fundamental to the long-term success of the Project and will continue to place a priority on identifying affected groups and working collaboratively with them to manage concerns throughout the lifecycle of the Project.

WCOL is in discussions with the Lheidli T'enneh First Nation with the intent to develop agreements that would define the terms of a meaningful and beneficial relationship between the parties related to the Project and other facilities and activities that would comprise the overall ethylene supply chain.

WCOL believes strongly in the need to engage often and early with the local community and various stakeholders to clearly explain the scope of the Project and then obtain feedback about the benefits and potential concerns related to the Project. WCOL will work with stakeholders to address concerns in a timely and responsive manner.

Further information regarding the previous activities, activities to date and on-going and proposed consultation activities is provided in Section 5.

1.5 Regulatory Context

WCOL has reviewed the *Regulations Designating Physical Activities* (Government of Canada, 2012) under the *Canadian Environmental Assessment Act, 2012* (CEAA 2012), SC 2012, c. 19, s. 52, as well as the draft *Physical Activities Regulations* (Government of Canada, 2019) under the *Impact Assessment Act*, pending this new legislation coming into force on August 28, 2019, and has determined that the Ethylene Project does not meet the criteria for a designated project. WCOL therefore anticipates that the Ethylene Project will not be subject to a federal review.

Further, WCOL has completed an assessment of the Project scope against the thresholds identified in the BC regulations, and as a result it is anticipated that the Project will require a review under *Reviewable Projects Regulation* of BCEAA. (Government of BC, 2002).

Comparison of the Project scope against the relevant provincial threshold is provided in Table 1.2.

Table 1.2: Comparison of Project Scope Against BCEAA Threshold.

Category	BC *Environmental Assessment Act* Criteria/Threshold	Relevant Project Component/Capacity
Organic and Inorganic Chemical Industry (Table 1 in *Reviewable Projects Regulation*)	A new manufacturing facility that has the production capacity of ≥ 100,000 t/y.	The Project has an ethylene production capacity of 1 Mt/y, which is above the guideline of 100,000 t/y. This category is the reason that the Ethylene Project is moving forward with a BC EA

The Project is not located in an area that has been the subject of a federal regional environmental study as defined in CEAA 2012.

WCOL will submit an EA Application for the Ethylene Project, as scoped out in this Project Description. As required by the BC Oil and Gas Commission (BC OGC), WCOL will also initiate an application with the BC OGC for the separate approval of this Project.

It is not anticipated that an EA will be required under a First Nations treaty or agreement.

Municipal rezoning of the proposed Project Area to heavy industrial designation is required with the City of Prince George.

Based on the Project's current design state, it is anticipated that the following Federal and Provincial permits and authorizations will be required. It is important to note that this list is preliminary and subject to change as the Project progresses.

Table 1.3: Expected Regulatory Requirements.

Permit/Authorization	Relevant Project Activity	Applicable Legislation/ Regulation	Responsible Agency
Federal			
Fisheries Act Self-Assessment or Authorization	Required if Project activities will likely result in serious harm to fish that are part of a commercial, recreational, or Indigenous fishery, or to fish that support such a fishery. May be required for water withdrawal from the Fraser River.	*Fisheries Act*, RSC 1985, c. F-14	Fisheries and Oceans Canada
Navigable Waters Notice of Works	Required for the construction of a work in a scheduled navigable waterway unless classified as a designated work under the Minor Works Order. May be required for water withdrawal from the Fraser River.	*Navigation Protection Act*, RSC 1985, c. N-22	Transport Canada
Aeronautical Obstruction Clearance	Required for tall structures that may interfere with air navigation, which may include buildings and Flare Stacks.	*Aeronautics Act*, RSC 1985, c. A-2; *Canadian Aviation Regulations*, SOR/96-433	Transport Canada
Non-objection to land use and construction proposals	Required for tall structures that may interfere with air navigation, which may include buildings and Flare Stacks.	*Aeronautics Act, Canadian Aviation Regulations*, and various zoning regulations and orders	NAV CANADA

Permit/Authorization	Relevant Project Activity	Applicable Legislation/ Regulation	Responsible Agency
Species at Risk Act Permit	May be required if any Project activities or components affect a Schedule 1 (*Species at Risk Act*) listed species or any part of its critical habitat or the residences of its individuals.	*Species at Risk Act*, SC 2002, c. 29	Environment Canada, Fisheries and Oceans Canada and Parks Canada
Provincial			
Environmental Assessment Certificate	Required prior to obtaining other Provincial permits or constructing the Project.	BCEAA	BC EAO
Facility Permit, including Leave to Construct and Leave to Operate	Required prior to any construction activities for the Project and for operation of the facility.	*Oil and Gas Activities Act*, SBC 2008, c. 36	BC OGC
Decision for an Exclusion of land from the Agricultural Land Reserve (ALR)	May be required to remove land from the ALR to allow for industrial activities.	*Agricultural Land Commission Act,* S.B.C. 2002, c. 36 *Agricultural Land Reserve Use Regulation,* B.C. Reg. 30/2019 *Agricultural Land Reserve General Regulation,* B.C. Reg. 171/2002	BC (supported by the Agricultural Land Commission)
Heritage Site Alteration Permit	May be required during the construction phase to alter an archaeological site within the Project footprint, if any archaeological site(s) is confirmed to exist during an archaeological overview or impact assessment.	*Heritage Conservation Act*, RSBC 1996, c. 187	BC OGC (supported by Archaeology Branch, BC Ministry of Forests, Lands, Natural Resource Operations and Rural Development)

Permit/Authorization	Relevant Project Activity	Applicable Legislation/ Regulation	Responsible Agency
Wildlife Salvage Permit	May be required for site preparation during pre-construction, construction and operation phases if wildlife salvages and bird nest removal or relocation are necessary.	*Wildlife Act*, RSBC 1996, c. 488	BC OGC (supported by BC Ministry of Forests, Lands, Natural Resource Operations and Rural Development)
Waste Discharge Permit(s)	Required prior to discharge of effluent (e.g., water from process operation) to the environment; release of air emissions; and management of solid waste.	*Environmental Management Act*, SBC 2003, c. 53; *Waste Discharge Regulation*, BC Reg. 320/2004; *Oil and Gas Waste Regulation*, BC Reg. 254/2005; *Petroleum Storage and Distribution Facilities Storm Water Regulation*, BC Reg. 168/94; *Hazardous Waste Regulation*, BC Reg. 63/88	BC OGC (may be supported by BC Ministry of Environment and Climate Change Strategy)
Registration under the Code of Practice for the Concrete and Concrete Products Industry	May be required if a concrete batch plant is used on-site during construction.	*Environmental Management Act; Waste Discharge Regulation*	BC OGC (may be supported by BC Ministry of Environment and Climate Change Strategy)
Water Licence	Required prior to withdrawal of surface water or groundwater.	*Oil and Gas Activities Act; Water Sustainability Act*, SBC 2014, c. 15	BC OGC (may be supported by BC Ministry of Forests, Lands, Natural Resource Operations and Rural

Permit/Authorization	Relevant Project Activity	Applicable Legislation/ Regulation	Responsible Agency
Notification(s) or Change Approvals for Changes in and about a Stream	Notification is required prior to undertaking an authorized change in and about a stream as defined in section 39 of the *Water Sustainability Regulation*. A change approval is required prior to undertaking any other type of change.	*Water Sustainability Act; Water Sustainability Regulation*, BC Reg. 36/2016	BC OGC (supported by BC Ministry of Forests, Lands, Natural Resource Operations and Rural Development)

In addition, WCOL anticipates the following Municiple permits/authorizations. This list is preliminary, and will be updated and refined as the Project progresses:

- A Servicing Study will be required for the Project, that would discuss the services needed for Project on the site to meet the City of Prince George Subdivision and Development Servicing Bylaw No. 8618, 2014. The Serving Study will include water modelling, need for main extensions, fire flows, and review of City Master plans for water and sewer Development Permit(s) (Servicing Brief required to address technical issues related to water supply, sanitary sewer collection and storm drainage system designs, with consideration the City's Municipal Master Plans).
- Building Permit(s).
- Plumbing Permit(s).
- Permit to Construct in City roadway (for any work proposed within the City road right of way i.e. sewer and water main extensions).
- Works and Services Agreements for work completed by WCOL within the City road right of way.

Additional provincial and municipal authorizations may be required if a temporary camp is required to house a portion of the construction workforce required to support the combined construction of the Project, the NGL Recovery Plant and the Derivatives Plant.

1.6 List of Contributors to Project Description

Table 1.4: Document Contributor Information.

Contributor	Credentials	Section(s)	Relevant Experience
Kevin C. Dorma	PhD, P.Eng. (Alberta)	3 – Project Overview	Professional engineer with over 20 years' experience across the oil, gas and petrochemical industry. Specific ethylene experience at Alberta ethylene plants specializing in quench water management, amine treating, GHG emission quantification and GHG reduction initiatives.
Laura Byrne	B.A.Sc.	1 – Introduction 3 – Project Overview 4 – Project Location, Land and Water Use	Graduate chemical engineer from Queen's University in April 2019.
Ronald Just	B.A.Sc, P.Eng. (APEGA, PEGBC)	Contribution to and review of all sections	Professional engineer with over 30 years' experience in oil, gas, and petrochemical facility design, construction and operation. 15 years' specific ethylene experience in engineering and business development roles with Nova Chemicals; lead engineer for major portions of ethylene 3 facility design and operation (2000 start-up).
Kenneth G. James	B.A.Sc, P.Eng. (APEGA)	2 – Ethylene Supply Chain 6 – Engagement and Consultation	Professional engineer with over 30 years' experience in oil, gas, and petrochemical facility design, construction and operation. Specializing in business development, plant design and operations optimization, Ken has direct experience in over 10 ethylene / polyethylene complexes worldwide.

Contributor	Credentials	Section(s)	Relevant Experience
Glenn Isaac	B.Sc. EP QAES	5.1.2- Freshwater Environment 5.3 – Potential Environmental Effects	Senior Aquatic Scientist with approximately 25 years of experience providing technical expertise related to data collection and impact assessment analysis with a focus on aquatic resources for projects and activities of varying scope and complexity at locations across western Canada including British Columbia, Alberta and the Northwest Territories.
Ruth Hardy	M.Sc., P.Ag.	4.2 -Land Ownership and Legal Description; 4.5 - Land Use Plans	Senior environmental impact assessment practitioner with over 15 years of experience that includes land and water use assessment, community and land use planning, land suitability analysis and soil and terrain survey and analysis.
Jay Brogan	M.Sc., R.P.Bio.	5.1.3 - Terrestrial Environment	Wildlife biologist with over 10 years of experience in western Canada including impact study design and assessments, and wildlife feature evaluations for major energy projects.
Mark Milner	B.A.Sc., M.Eng., P.Eng.	5.1.1 - Atmospheric Environment	Senior atmospheric environment specialist with 20 years of experience in air quality, noise, greenhouse gas, odour, and light assessments within the mining, transportation, oil and gas, industrial and forestry sectors.

Contributor	Credentials	Section(s)	Relevant Experience
Nina Barton	B.Sc., MRM	5.2 – Social, Economic, Health and Heritage Setting	Senior researcher with over 15 years of diverse interdisciplinary experience, including environmental and socio-economic assessment, environmental planning and Indigenous land use for major resource projects.

2 Project Overview

This section provides an overview of the Project, describes the Project-related components and activities, summarizes the emissions, discharges and wastes associated with the Project and provides a summary of the Project schedule.

2.1 General Project Description

This Project Description pertains to the Ethylene Project, which includes the Ethylene Plant, and all directly associated utilities and infrastructure. Located within the Project Area in Prince George's industrial park, the Ethylene Plant will purchase ethane feedstock from the NGL Recovery Plant and convert it primarily into ethylene product (roughly 80% of the total production from the facility), hydrogen-rich offgas and some mixed liquid coproducts. The ethylene product will be sold to a third-party Ethylene Derivative Plant as feedstock to manufacture products such as polyethylene or mono-ethylene glycol. Offgas will be used as fuel within the Ethylene Plant; its hydrogen-rich composition will reduce GHG emissions associated with the facility. The liquid coproducts consist of 4 products:

- A mixture of propylene, propane and other compounds containing 3 carbons (mixed C3)
- A mixture of butadienes, butene, butane and other compounds containing 4 carbons (mixed C4)
- Aromatic Concentrate
- Pyrolysis Fuel Oil

These coproducts will be loaded onto rail cars by facilities owned and operated by the NGL Recovery Plant and likely sent to petrochemical hubs in Alberta or the USGC.

2.2 Project Environmental and Socioeconomic Benefits

2.2.1 Socioeconomic Benefits and Competitive Advantage

The $2.0 billion to $2.8 billion Project will generate thousands of person-years of employment during the construction period and up to 230 permanent direct plus contract employee positions once the Project reaches commercial operation. Once the plants are in operation, there will be a need for approximately $20 million to $50 million per year of sustaining capital investment that will generate significant on-going economic benefits to the local community.

The numerous other indirect benefits to the local community will include training at local institutions (UNBC and CNC), opportunities to provide support services (transport, food, lodging, maintenance, professional services, etc.), and new associated business development opportunities.

One important aspect of the WCOL Project is the inclusion of the ethylene and polyethylene plants that create a new demand market for ethane in BC. Ethane is the most abundant natural gas liquid product that is present in natural gas but the only current market in Western Canada is the Alberta petrochemical hubs at Joffre and Fort Saskatchewan. The WCOL Project is an important first step to add value to BC's natural gas industry and to provide economic diversification into a new industry segment.

Low-cost feedstock and efficient access to Asian markets are the key competitive advantages of the WCOL Project over similar plants in Alberta or on the USGC.

The shale gas revolution that has occurred over the past ten years has changed the global natural gas supply and pricing structure and this is likely to prevail for the foreseeable future. Historically, Western Canadian gas production has largely been exported to Eastern Canadian and US markets. Shale gas production from formations such as the Marcellus in the US Northeast has grown to a scale that now surpasses total Western Canadian production and is eroding Canada's historic export markets. Consequently, Western Canada has some of the lowest natural gas prices in the world as Western Canadian production is being delivered into an over-supplied US market with few other options.

Domestic North American production capacity of polyethylene and mono ethylene glycol now exceeds North American demand and substantially all new production will be destined for large and growing Asian markets. BC has a significant advantage for export of products into the growing Asian market, when compared to the USGC or Alberta (see Figure 2.1). Product shipped from BC's west coast will have less than half the travel time of USGC shipments, and unlike the USGC cargoes, will avoid the added cost of toll payments through the Panama Canal.

For polyethylene produced from ethane feedstock, the combination of feedstock, fuel and product logistics movements can comprise over 85% of the variable costs of the product manufacture. The WCOL project has structural advantages over key competitors and this positions our facilities to be a low-cost global producer.

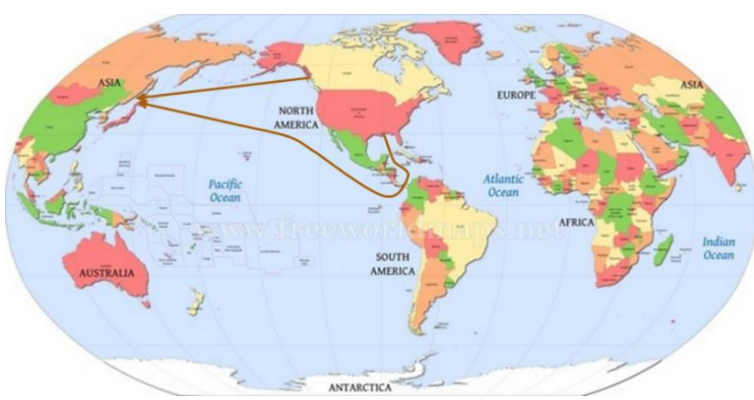

Figure 2.1: Delivery pathways to Asian markets between USGC and WCOL Shipments.

2.2.2 Environmental Benefits

In addition to delivering tremendous economic benefits to the communities within which we work, WCOL is committed to best-in-class environmental performance. The Project scope has been developed to minimize local environmental impact and achieve carbon footprint reductions. The following lists some of the large-scale environmental benefits or opportunities associated with the Project:

- Using ethane as the feed to an ethylene plant results in the simplest chemistry and lowest energy consumption process for manufacturing ethylene, creating an energy and emissions advantage against other feedstocks used globally.
- The WCOL Project will utilize the latest technology in the design of the Ethylene Plant, resulting in directionally lower emissions than older facilities operating globally today. Ethylene technology licensors claim a 30% reduction over the past 20 years in energy consumption and emissions from ethane-based ethylene plants.
- Due to on-going airshed issues within Prince George, odour and levels of atmospheric particulate matter with a diameter of less than 2.5 micrometres ($PM_{2.5}$) are of great concern for the Prince George population. The primary fuels for the Project will be Ethylene Plant offgas, that consists of mostly hydrogen and methane, and lean natural gas. These are very clean-burning fuels that emit no odour and negligible particulate matter. The Project will be designed with vapour recovery systems and fugitive emission monitoring systems to minimize fugitive emissions and odours.
- The Project proponent will minimize land disturbance by locating the Project Area on fee simple land in an under-utilized, existing industrial park within the Prince George city limits. Required amenities and utilities for the plant, including power supply, rail and access routes exist close to the site, and thus limited additional construction or tie-ins will be required.
- WCOL will design and operate its facilities to minimize impacts on the important fisheries of the Fraser and Nechako Rivers. The majority of the water used by the Project will be for non-contact cooling water in a circulated cooling water system to minimize the volumes required and minimize the risk of contamination by the petrochemical process. The plant will be designed to treat and recycle process water streams wherever practical. Any water that is released into the river will be cooled in the cooling water circuit, treated and tested to ensure that it exceeds all regulatory standards.
- As noted above, the combination of using ethane as a feedstock, combined with a new plant utilizing the latest technology, results in a facility which will have very high energy efficiency and low GHG emissions per tonne of ethylene produced. An ethane cracker with low input gas pricing will compete favourably against Asian facilities operating on

higher-cost, higher-emissions feedstocks. So the WCOL Project is well positioned to displace these high-cost facilities and reduce carbon footprint on a global basis.

- A large amount of low-grade waste heat is available from an ethylene facility; this waste heat will be rejected to the atmosphere via the Cooling Tower. However, this heat could instead be used for low-grade heating, such as a greenhouse operation. WCOL is working to identify interested third parties who will own and operate a greenhouse to grow tree seedlings for reforestation, utilizing the waste heat from the Ethylene Plant.

2.3 Project Components and Activities

2.3.1 Project Components

The WCOL Ethylene Plant will convert approximately 4,000 tonne per day (t/d) (approximately 11,000 cubic metres per day (m^3/d)) of high-purity ethane feedstock, purchased from the NGL Separation Plant into approximately 3,000 t/d of high-purity ethylene, which will be sold to a third-party Ethylene Derivative Plant to produce various grades of polyethylene for the expanding Asian market. The conversion process will also produce byproduct offgas (hydrogen and methane mixture) and small amounts of a mixed C3 stream, a mixed C4 stream, Aromatic Concentrate and Pyrolysis Fuel Oil.

The process will consume fuel (lean natural gas and byproduct hydrogen) to provide the heat needed for the conversion of the ethane. The products and coproducts will be separated and purified through distillation, which requires various heating and cooling utilities.

The Ethylene Plant process will require the following main process units:

- Feed preparation
- Pyrolysis Furnaces
- Quench water and dilution steam system
- Pyrolysis gas compression, Deethanizers, and Acetylene Reactors
- Chilling Train and Demethanizer
- C2 Splitter
- Coproduct Fractionation
- Refrigeration
- Ethane Feed and Ethylene Product Storage

Figure 2.2 provides an overview of the relationships between the facilities.

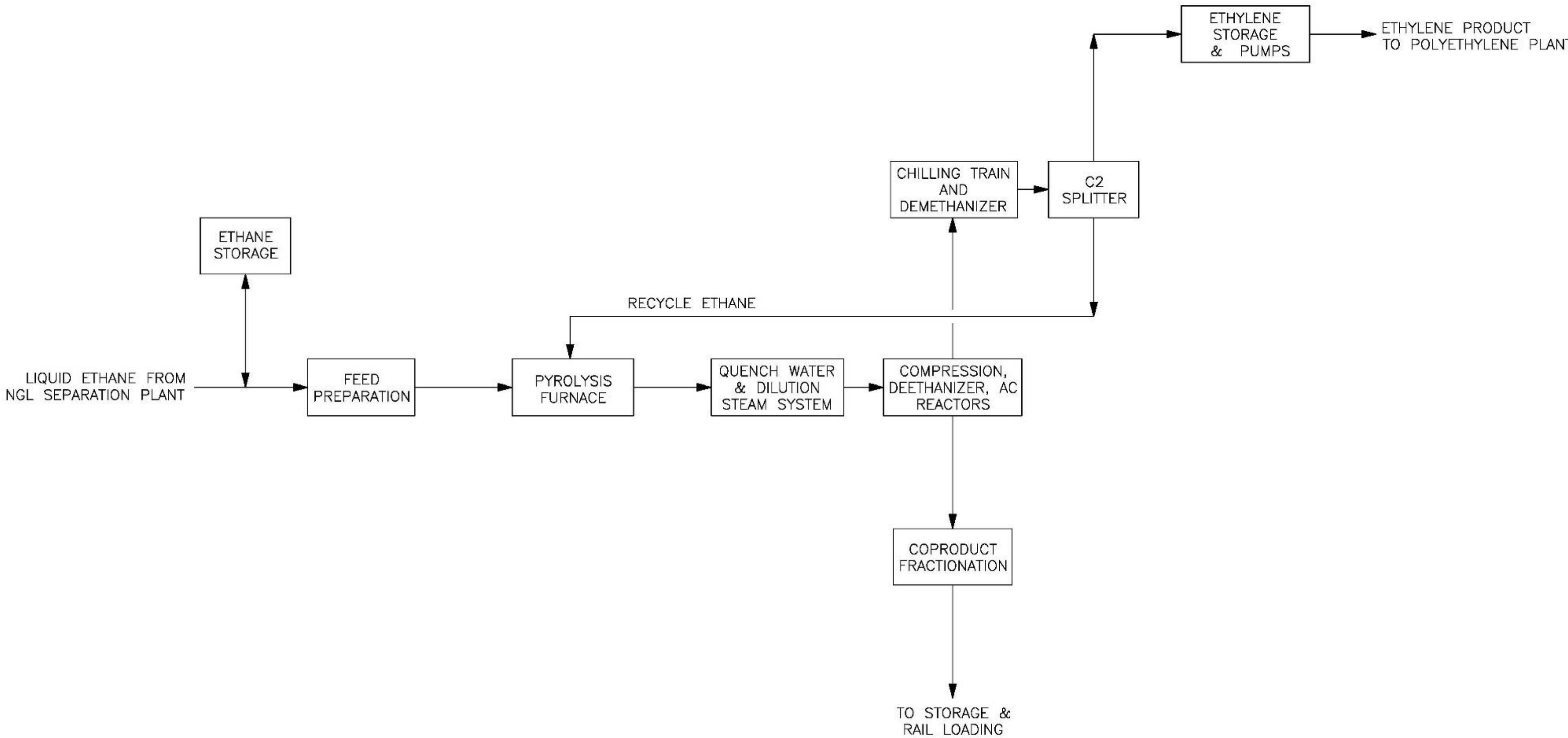

Figure 2.2: Relationships Among Key Components of the Ethylene Plant.

Individual units associated with the key components of the Ethylene Project are summarized in Table 2.1. Key components are described in further detail in the following sub-sections. At this stage, WCOL has completed preliminary engineering; thus, capacities are subject to change as engineering design progresses.

Table 2.1: Summary of the Ethylene Project's Major Components.

Key Components, Capacities and Purposes	Individual Units
Feed Preparation Plant Approximately 4,000 t/d (approx. 11,000 m^3/d) of fresh ethane will be used as feedstock for the Ethylene Plant Approximately 1,300 m^3 of ethane storage will be provided. A sulphur-based chemical (such as dimethyl sulphide or dimethyl disulphide) will be added to control coking rates in Pyrolysis Furnaces.	• Heat exchangers and process vessels • Amine treatment system, including Amine Contactor and Regenerator towers, filters, pumps, heat exchangers, storage tanks, and chemical injection • Horizontal storage vessels • Chemical storage and injection system

Pyrolysis Furnaces
Approximately 6,000 t/d of fresh and recycled ethane will be consumed by the Furnace, which will convert nominally 65% of the feed to ethylene and coproducts. Note: unconverted ethane will be recycled back as furnace feed.
The fired duty of each furnace will range between 375 and 425 gigajoules per hour on a lower heating value (LHV) basis. (GJ_{LHV} /h)
	• Up to 6 Pyrolysis Furnaces to convert ethane to ethylene
	  ○ Between 30 and 50 m in height plus a stack between 8 and 15 m tall, for a cumulative total of up to 65 m tall
	• Each furnace will include:
	  ○ Refractory-lined radiant box
	  ○ Refractory-lined convection section and furnace stack
	  ○ Convection section exchanger banks
	  ○ Induced draft fan
	  ○ Forced draft fan, combustion air preheat system and ducting (likely)
	  ○ Heat exchangers
	  ○ Steam drum
	  ○ Ultra-low NOx burners and burner management system

Key Components, Capacities and Purposes	Individual Units
Quench Water and Dilution Steam System Approximately 8,000 t/d of furnace output (charge gas) will be quenched (cooled), and process water will be recovered for use as dilution steam.	• Quench Tower ○ Up to 7 m in diameter x up to 70 m high • Process vessels • Process equipment (such as filters) • Process water stripping tower(s) • Vaporizers • Heat exchangers

Pyrolysis Gas Compression, Deethanizers and Acetylene Reactors
 	
The cooled charge gas will undergo compression, as well as water and CO_2 removal. Approximately 6,000 t/d of treated charge gas will be fed to the Deethanizer system, where heavy coproducts will be separated from the ethane and lighter hydrocarbons in the charge gas stream, and acetylene (a byproduct of pyrolysis) will be converted to ethylene.
	• Centrifugal compressors driven by steam turbines
	    ○ Total power input required of 45 to 60 MW
	• Compressor intercoolers
	• Treatment system including Caustic Tower
	• Dehydration system
	• One or 2 Deethanizer distillation towers
	    ○ Up to 5 m diameter x up to 30 m high
	• Acetylene Reactor system
	• Miscellaneous heat exchangers, vessels and pumps

Chilling Train and Demethanizer Charge gas from the Acetylene Reactors will be processed in the Chilling Train to separate ethylene and unreacted ethane from the offgas byproduct (methane, hydrogen and CO) Approximately 500 to 700 t/d of offgas will be produced and used as fuel in Pyrolysis Furnaces.	• Brazed aluminum heat exchangers • Separation vessels • High-speed vapour Expanders and Compressors • Demethanizer distillation tower • Multiple diameters ranging up to 6 m x 45 to 55 m high

Key Components, Capacities and Purposes	Individual Units

C2 Splitter
The C2 splitter will separate the ethylene product from unreacted ethane. Approximately 3,000 t/d of ethylene product will be produced.
1,300 m^3 of ethylene storage will be provided
	• C2 Splitter distillation tower
	  ○ 5 to 6 m diameter x 55 to 65 m high
	• Heat pump compressor, with steam turbine driver
	  ○ <20 MW power input required
	• Brazed aluminum and shell and tube heat exchangers
	• Centrifugal pumps
	• Horizontal storage vessels

Coproduct Fractionation
Separate the coproducts into 4 product streams:
• Mixed C3 (approx. 100 t/d to 125 t/d)
• Mixed C4 (approx. 100 t/d to 125 t/d)
• Aromatic concentrate (approx. 150 t/d to 200 t/d)
• Heavy pyrolysis fuel oil (approx. 25 t/d to 50 t/d)
	• Up to 4 distillation towers to separate components
	  ○ Depropanizer
	  ○ Debutanizer
	  ○ Potentially two Aromatic Concentrate towers
	• Heat exchangers, such as reboilers, condensers and product coolers
	• Storage vessels and tanks
	• Centrifugal pumps

Refrigeration Provide refrigerants at temperatures ranging from -100 degrees Celsius (°C) and 0°C for removing heat from the process.	• Centrifugal compressor systems with steam turbine drivers ○ 5 MW to 15 MW power input required • Heat exchangers and process vessels

Feed Preparation

The Ethylene Plant will receive approximately 4,000 t/d (11,000 m^3/d) of ethane as a pressurized liquid from the NGL Separation Plant via the Transfer Line. Ethane feed storage will be provided to maintain steady operation of the NGL Recovery Plant and the Ethylene Plant.

The ethane liquid will be vapourized and preheated and then passed through an amine system to remove both CO_2 and traces of H_2S from the ethane. CO_2 and H_2S will then be sent to the Pyrolysis Furnace firebox to ensure complete destruction of H_2S and trace hydrocarbons.

Treated ethane will be mixed with recycled ethane and dilution steam before entering the Pyrolysis Furnaces. A low-dose sulphur agent will be added to the heated mixture to control coke formation in the Pyrolysis Furnaces.

Pyrolysis Furnaces and Quench System

Approximately 6,000 t/d of fresh and recycled ethane will be fed to the Pyrolysis Furnaces. The ethane feed will be mixed with approximately 2,000 t/d of dilution steam. The dilution steam will be added to reduce coking (build-up of carbon deposits on furnace coils).

The Pyrolysis Furnaces will heat the feed to convert roughly 65% of the ethane, primarily into ethylene. Several byproducts are also produced by the furnaces, including hydrogen, methane, acetylene, propylene and heavier hydrocarbons.

The hot reaction products, known as charge gas, will leave the furnace after which they will be cooled (quenched) to prevent further unwanted side reactions. Heat is recovered during the cooling of the charge gas by generating VHP steam. This generated steam will be used at different pressure levels to drive various steam turbines and provide heat to the process, resulting in a very energy efficient design.

The furnace fuel will be a mixture of hydrogen and methane recovered from the charge gas, plus supplemental lean natural gas. Usable heat will be removed from the hot combustion gases to heat the ethane feed, boiler feed water and very high pressure (VHP) steam, before the combustion gases are sent to atmosphere through the furnace stack. The overall thermal efficiency of the Pyrolysis Furnaces will range from 90 to 94%.

The Pyrolysis Furnaces will also require periodic decoke cycles to remove coke from the inside surface of the tubes. The effluent resulting from this process will be sent back to the firebox of the furnace to be combusted to CO_2 before being discharged to the atmosphere from the furnace stack.

Quench Water and Dilution Steam System

Final cooling of the charge gas will be completed in the Quench Tower, where cool water (quench water) will directly contact the hot charge gas.

Water present within the charge gas (added as dilution steam to the furnace feed) and heavy C5+ hydrocarbons (oil) will condense within the Quench Tower. The quench water will go through the following processes, which are intended to clean the water to allow maximum recycle and reuse:

- Bulk separation of free oil
- Removal of coke fines and heavy hydrocarbons through a combination of coalescing, gravity settling or flotation
- Removal of dissolved light hydrocarbons by steam stripping

The clean quench water will then be vapourized to generate dilution steam, which will be mixed with the ethane feed to the furnaces.

The condensed oil will be delivered to the Aromatic Concentrate Recovery Unit.

Charge Gas Compression, Deethanizers and Acetylene Reactors

The charge gas must be compressed to separate the ethylene product and unreacted ethane from other byproducts. This compression will be carried out with a multi-stage, intercooled compressor, driven by steam turbines.

Water and hydrocarbons are condensed throughout the compression system. The water is recycled to the Quench Tower and the hydrocarbons are delivered to the Aromatic Concentrate Recovery Unit.

Compressed charge gas will undergo treatment within the Caustic Tower where most of the remaining CO_2 will be removed (less than 5 parts per million will remain in the ethylene produced by the plant).

After the final compression stage, the gas will be cooled and water will be removed in driers.

Compressed charge gas will be fed to the Deethanizer system, where the heavy byproducts (C3 and heavier) will be separated from the lighter product (ethylene), unreacted feed (ethane), acetylene and lighter hydrocarbons (hydrogen, methane, carbon monoxide, etc.).

As the acetylene in the charge gas can deactivate catalysts in downstream derivative processes, the acetylene will be converted to ethylene within the Acetylene Reactor, prior to the separation of ethane and ethylene.

It should be noted that there are multiple ethylene technologies available and the detail of how the processes in this section are integrated together will be developed and design of this system will be finalized as engineering progresses.

Chilling Train and Demethanizer

Charge gas from the Acetylene Reactor will be sent to the Chilling Train, a series of heat exchangers, Turbo Expanders and a “cold box” (a brazed aluminum heat exchanger) where the gas will be cooled to roughly -150°C.

Cold liquids condensed and recovered at various points in the Chilling Train will be fed to the Demethanizer to separate the ethane and ethylene from the light gases (hydrogen, methane and carbon monoxide (CO)). Hydrogen-rich gas from the Demethanizer overhead will be cooled via the Turbo Expanders to provide refrigeration and then compressed, producing approximately 600 t/d of offgas (hydrogen, methane and CO). The offgas will be sent to the plant fuel gas system to be used as low-emissions fuel gas. The stream which exits the bottom of the Demethanizer (bottoms stream) will be fed to the C2 Splitter.

C2 Splitter

The C2 Splitter will receive approximately 5,000 t/d of bottoms product from the Demethanizer and will separate the ethylene product from the unconverted ethane. The overhead ethylene vapour from the C2 Splitter is the primary product from the Ethylene Plant. Unreacted ethane will be recovered from the bottom of the distillation tower and recycled back to the Pyrolysis Furnaces.

The design of this system varies between ethylene licensors. The ethylene from the overhead of the C2 splitter is often incorporated into a refrigeration system to provide heating and cooling for the distillation process, often in a process referred to as a heat pump. The design, operating conditions and power requirements will be finalized during future engineering.

A small amount of working storage will be provided for the liquid ethylene product. Approximately 3,000 t/d of ethylene product will be produced and pumped to derivative customers.

Coproduct Fractionation

Separation of the heavier byproducts will be achieved by feeding the C3+ hydrocarbons from the Deethanizer system to a series of distillation towers, with the light product stream being recovered from the overhead of the tower and the heavier bottom stream being sent to the next tower. These towers are the Depropanizer and the Debutanizer:

- The Depropanizer will take the C3+ stream from the Deethanizer, produce the mixed C3 product as the overhead, and deliver the bottom C4+ stream to the Debutanizer. The C3 product will primarily consist of propylene and propane. Approximately 100 t/d to 125 t/d of mixed C3 product will be produced.
- The Debutanizer will take the C4+ stream from the Depropanizer, produce the mixed C4 product as the overhead, and produce an Aromatic

Concentrate stream from the bottom. The C4 product will primarily consist of butadienes and butenes. Approximately 100 t/d to 125 t/d of mixed C4 product will be produced.

Aromatic coproduct resulting from the Quench Tower and charge gas compression will be fed to the Aromatic Concentrate Recovery Unit (ACRU). The Aromatic Concentrate generated from this unit will be combined with those recovered from the Debutanizer bottoms. Approximately 150 t/d to 200 t/d of this Aromatic Concentrate will be produced. Approximately 25 t/d to 50 t/d of the heavier Pyrolysis Fuel Oil will be produced.

These products will be stored on-site, and subsequently transported via rail to either US or Alberta petrochemical markets. The assets related to the storage and loading of these liquid coproducts are expected to be owned and operated by the NGL Separation Plant.

Refrigeration

The ethylene production process will require refrigeration at very low temperatures. Two refrigeration systems are typically used to meet the cooling requirements for the process: a mixed propylene refrigerant and an ethylene refrigerant. Design is dependent on final design by the ethylene licensor and concepts will be completed as engineering progresses.

Storage

Ethylene Plant product storage volumes are described in Table 2.2. It is important to note that ethylene coproducts (mixed C3, mixed C4, Aromatic Concentrate coproduct, and Pyrolysis Fuel Oil coproduct) will be stored within the General Hydrocarbon storage farm owned by the NGL Separation Plant. Storage requirements will be sold as a service to the Ethylene Plant by the Separation Plant. Thus, this storage is outside the level of detail required for description of the key components of this Project's EA. Storage requirements for the ethylene coproducts are presented within Appendix C.

Table 2.2: Product Storage in the Ethylene Plant.

Product	Storage Type	Purpose of Storage	Total Working Volume	Shipping Strategy
Ethane Feed	Bullet (x3)	To permit steady operation of the Ethylene Plant, specifically the Pyrolysis Furnaces. Will ensure ethane feed rate remains steady against any changes in the upstream facilities and will ensure sufficient ethane volume to allow proper shutdown of Pyrolysis Furnaces in the event of total ethane loss from the Separation Plant. The storage will also allow the NGL Recovery Plant to transition to only recover C3+ when the Ethylene Plant shuts down.	Approximately 1,300 m^3 (approximately 430 m^3 per bullet) pressurized liquid (horizontal vessels). Volume and number of bullets to be finalized.	Pump to Feed Preparation portion of Ethylene Plant as pressurized fluid
Ethylene Product	Bullet (x3)	To provide storage capacity of 4 hours so as to provide ethylene to the downstream Derivatives Plant should there be a process upset in the Ethylene Plant. This will allow the Derivative Plant to continue to operate and begin a controlled shutdown of facilities, depending on the length and severity of the upset. Or in event of a Derivative Plant shutdown, the storage can be used to effect a controlled shutdown of the Ethylene Plant.	Approximately 1,300 m^3 (approximately 430 m^3 per bullet) pressurized liquid (horizontal vessels). Volume and number of bullets to be finalized.	Pump to adjacent Ethylene Derivative Plant as pressurized fluid

2.3.2 On-site Utilities

The Ethylene Plant will be the predominant consumer of the utility and infrastructure requirements in the Project Area. Some of the equipment will be constructed and operated as part of the Ethylene Plant and will be physically located within the plant boundaries and adjacent to process equipment, because of how closely it is integrated to the design of the Ethylene Plant. Other utility systems, such as tie-ins to power supply, will be physically located in a general utility area and could be expanded in the future to provide utilities to multiple plants if there is a capacity expansion at the site. At the present stage of the Project, all utilities related to the Ethylene Project are described in this section without discussion of specific locations; additional detail will be provided with the Application.

Certain infrastructure and utilities will be provided as a service and sold to the NGL Separation Plant by the Ethylene Project. This distribution of utilities is represented in Appendix D.

Individual units of the key components of the Ethylene Project are summarized in Table 2.3. Key components are described in detail in the following sub-sections.

Table 2.3: Summary of On-site Utilities for the Ethylene Project.

Key Component, Capacity and Objective	Individual Components
Raw Water System Designed to withdraw and treat a raw water supply of approximately 600 to 650 m^3/h.	• Water inlet, fitted with adequate screening or raw water supply wells • Treatment system • Pumps • Raw water storage
Cooling System Circulate between 25,000 and 35,000 m^3/h of cooling water Reject up to 1,500 GJ/h of heat via evaporation	• Cooling Tower basin, pumps, fans and circulating underground pipe system • Cooling water chemical treatment system • Blowdown treatment and river water return
Steam System Capacity to produce up to 450 t/h of VHP steam, to recover useful heat from the Pyrolysis Furnaces and ensure steam supply matches the demand from the large turbine drivers	• Demineralized water treatment system • Deaerator, water storage, pumps • Pressure letdown and desuperheater control stations • Piping distribution headers for boiler feed water and multiple steam pressure levels • Condensate collection and treatment system • Blowdown treatment system • Utility boiler
Effluent System	• Adequate pH adjusting and treatment systems • Discharge pumps
Supporting Systems	• Fire water system • Stormwater containment and treatment system • Wastewater collection system • Flare system • Instrument and utility air • Utility nitrogen • Potable and utility water • Project infrastructure • Methanol Circulation System • Utility Glycol Heat Medium System • Fuel Gas System • Utility boiler system

Water and Wastewater Treatment

For a more detailed description of water usage and distribution within the Ethylene Plant, refer to Section 3.

Raw Water System

Raw water will be diverted from either the Fraser River or from groundwater well sources, or a combination of the two, at approximately 600 to 650 m^3/h to meet the water make-up requirements of the Ethylene Plant. The raw water system will differ slightly depending on the raw water sources, but will likely include a water inlet, fitted with adequate screening, or raw water supply wells, followed by appropriate treatment to remove solids, organics and hardness as required. It is important to note that due to the high solids loading in the Fraser River, WCOL is evaluating the option of well water to supply raw water to provide Ethylene Plant water requirements. Raw water design will be developed prior to application.

The majority of the treated water will be sent to the Cooling Tower as make-up and the remainder will be sent to the Demineralized Water System for further treatment.

Circulating Cooling Water System

Cool supply water from the Cooling Tower is pumped and distributed through a network of underground piping and used to provide cooling requirements to numerous heat exchangers in the Ethylene Plant. As heat is removed from the process in the heat exchangers, it will heat up the cooling water. Warm cooling water will be returned to the Cooling Tower and cooled against ambient air. The cooled water will collect in a concrete basin in the bottom of the tower to be pumped again as cool supply water. The cooling water circulation rate will be between 25,000 and 35,000 m^3/h in the summer. Water loss will occur from the tower via evaporation and a minor amount of drift (entrained water droplets). A small blowdown stream, between 50 and 100 m^3/h, will be withdrawn from the tower to reduce the concentration of dissolved minerals, such as calcium, present in high amounts in the circulating water due to the evaporation. Suspended solids (dust and other particles scrubbed out of ambient air by the water) will also accumulate in the cooling water, and a small portion of the circulating water will be processed through sidestream filters to control solids content. Backwash effluent from the filters will join the blowdown from the system. Treated cooling water make-up will continuously be added to the tower to replace losses from evaporation, drift, blowdown and backwash. Chemicals will be injected to the cooling water system to control microbiological growth, prevent dissolved solids deposition and control pH.

Demineralized Water Treatment

A portion of the treated raw water from the Fraser River (or potentially well sources) will undergo ionic exchange treatment to remove minerals, which cause fouling in boilers. The resulting demineralized water will be very pure, containing low solid content. From 50 to 60 m^3/h of demineralized water will be provided to the Ethylene Plant, where it will be used as boiler feed water make-up, and to provide make-up water requirements where water has been lost (such as within amine treatment towers and caustic towers). The stream (approximately 20 to 30 m^3/day) that results from the regeneration of the ion exchange system will contain the dissolved salts that were captured in the ion exchange resin and the medium that is needed for regeneration. This demineralized regeneration residue stream will be combined with the treated blowdown stream from the Cooling Tower.

Effluent Treatment

The treated blowdown stream from the Cooling Tower will be combined with the demineralized regeneration stream. Approximately 70 to 120 m^3/h of combined blowdown will undergo pH adjustment and treatment to meet all effluent water quality requirements as required by operating permits before being discharged into the Fraser River.

Steam System

Very high-pressure steam (at roughly 10,500 kiloPascals gauge (kPag)) will be generated from waste heat in the Ethylene Plant and used at several different pressure levels to power steam turbine drivers and provide process heat to heat exchangers throughout the process. The majority of the steam will be condensed and recycled (minimal losses), but a small blowdown stream (1 to 2% of total steam production) will continuously be removed from the steam system to prevent hardness concentrations from cycling up and causing damaging deposits from occurring in the boiler tubes or heat exchange equipment. This blowdown will likely be recycled and used as make-up to the quench water system. Make-up water will continuously be added to the steam system to replace the blowdown and losses.

Dilution Steam System

Water that is present within the Pyrolysis Furnace effluent will condense within the upper portion of the Quench Tower. This water will contain small amounts of heavy C5+ hydrocarbons and will be treated through use of coalescing filters and steam stripping. This treatment removes most of the hydrocarbons so that the water can be recycled and reused to generate dilution steam. Trace amounts of dissolved hydrocarbons will exist within the treated quench water and a blowdown stream will be needed to reduce the possibility of build-up in downstream process units. This blowdown will likely be recycled and used as cooling water make-up.

Stormwater Containment

Stormwater falling on the developed portion of the site will be captured in a retention pond, pumped to a treatment system and recycled as cooling water make-up, to minimize the river or well water make-up required. As the layout of the NGL Separation Plant and Ethylene Project equipment is laid out on the site, there is potential that a single, integrated stormwater management system will be designed for the entire site. If so, this is expected to be an Ethylene Project asset.

Wastewater Collection

The facility will not have any waste collection systems open to the atmosphere. Any equipment with the potential to contain a mixture of water and hydrocarbons will have its normally operated vents and drains tied into either the flare or a closed hydrocarbon drain system, which will collect the streams, separate the oil and water and recycle the streams to the process where possible. Systems containing chemicals (e.g., the amine system, caustic system) will have local drain collection systems, which will be periodically recycled to the process when possible, or otherwise shipped off site for appropriate disposal.

Equipment that is located outdoors and has the potential for spills of liquid hydrocarbons or chemicals will be segregated from the general stormwater collection system with a dyke, berm or curb and a local collection sump. When rainwater collects in one of the segregated sump areas, it will be visually checked or tested released to the site stormwater collection system only if it is deemed clean. If contaminated, the water will be collected by vacuum truck and sent for safe disposal.

Fire Water System

The fire water system is a safety system that will be on standby at all times to provide water in the event of a fire. Hydrants and deluge systems, as required, will be tied into an integrated sitewide system, which will include an underground firewater distribution network. The system will consist of tanks, pumps and controls designed to meet National Fire Protection Association and other applicable codes and standards. This system will be designed to supply firewater needs for the NGL Separation Plant on a cost-of-service basis.

Miscellaneous Utilities

Flare System

The flare system will be a key safety system designed for the safe release of hydrocarbon during a serious plant upset or emergency. It will be comprised of a standard collection headers and Flare Stack(s). Vents and drains on hydrocarbon-containing equipment will not be released to atmosphere as part of normal operation or maintenance but will be piped directly into one of the flare headers to be captured. Temporary tubing will be used as an operating practice to tie abnormal vents and drains into the flare for unusual maintenance events.

Instrument and Utility Air

The purpose of the instrument and utility air system will be to deliver clean, dry air to control valves and other equipment in the plant. This system will consist of two 100% packaged units and an Instrument Air Receiver (sized for 30 minutes' supply of instrument air) to provide reliable backup supply. The moisture that is removed from the air will be directly disposed of to the sanitary sewer system because it will not contain contaminants.

Utility Nitrogen

A utility nitrogen package, including liquid nitrogen storage and an ambient temperature vaporizer, will be provided. A backup heater will also be provided to supply supplemental heat if necessary. Utility nitrogen will be used as an inert gas within storage tanks and to provide a seal on rotating equipment to reduce the discharge of volatile organic compounds (VOC).

Methanol

Methanol barrel storage will be provided for manual injection at process tie-in points to address any formation of hydrates in the process.

A circulating hot methanol system may also be provided for the Ethylene Plant, to provide a heat medium for specific services, namely emergency vapourization of the liquid ethane and vapourization coils in the cold flare drum(s). Methanol is considered for these services because it will not freeze when in contact with very cold process streams. The system will consist of a heat exchanger (steam heated), storage vessel and circulation pumps.

Glycol Tracing System

A circulating hot glycol system will be provided. The hot glycol will be used to provide anti-freeze protection for piping and equipment, such as glycol tracing of piping, heating coils in tanks. Detailed engineering will evaluate options such as electrical tracing, but the availability of excess low-pressure steam typically makes glycol tracing an attractive option in cold climate ethylene plants. The system will consist of a heat exchanger (steam heated), storage vessel, filters and circulation pumps.

Utility Boiler

A total of 2 boilers will be used to ensure that sufficient backup steam is available for specific process units within the Ethylene Plant, such as steam-driven turbines. These boilers will normally operate at minimum turndown to be ready to supply steam during plant upset conditions. The boilers will produce high-pressure steam at roughly 4,200 kPag.

Potable and Utility Water

Potable water will be used within various operations of the plant, including but not limited to eye washing stations, emergency showers, and kitchen and lavatory uses. Utility water will be provided at utility stations throughout the plant and will provide clean water for various maintenance operations such as the equipment and pad cleaning. Potable and utility water will be supplied from the Prince George Municipal water supply. Sanitary sewer collection will be included in all occupied buildings with standard washroom or kitchen facilities. Sanitary sewage and grey water will be collected and sent to the Prince George sewage collection system; no process water will be tied into the City sewage system.

Fuel Gas System

Fuel gas will be supplied to the Ethylene Plant from offgas produced within the Demethanizer and Chilling Train System. Make-up natural gas will be provided to the fuel gas system to ensure that the fuel demands of the Pyrolysis Furnaces are met. Because the offgas contains over 80% hydrogen (by volume) with most of the remainder being methane, the fuel has a very low GHG footprint.

Lean natural gas will be used for the utility boilers and the flare pilot.

Miscellaneous

A number of auxiliary systems are associated with some of the rotating equipment in the facility, which are not normally considered as independent utilities, but are listed here for completeness: compressor and pump lube oil systems, compressor seal gas systems, steam turbine sealing steam systems and pump seal systems.

Project Infrastructure

WCOL will develop all necessary infrastructure at the Project Area to accommodate the needs of on-site personnel. This infrastructure will include maintenance and support buildings, warehouses for equipment, site security infrastructure and laboratory services. Project infrastructure will include:

- Buildings

  Following is a list of buildings potentially required for the Ethylene Plant operation, but many of these buildings could be located in the City of Prince George or at other locations in the BCR industrial area. WCOL's operating strategy will be to minimize the number of personnel at the site by locating non-essential personnel to other locations. This strategy will reduce risk to personnel in the case of an event such as fire or evacuation at the site.

  - Control Room
  - Administration and engineering
  - Maintenance
  - Warehouse
  - Process equipment buildings (multiple)
  - Water treatment
  - Motor Control Centers (MCC)
  - Emergency response/medical
- Site Security
  - Fencing and controlled access gate
  - Closed circuit cameras and monitoring
  - Communications
- Emergency Response

  A mutual assistance arrangement will be discussed with City emergency response services. Initial emergency response will be by trained WCOL personnel, but secondary response could be provided by the City. WCOL equipment:

  - Fire truck
  - Ambulance
- Laboratory
- Control system and information systems

2.3.3 Project Activities

The following section outlines the general activities that will occur within the 3 main phases of the Project's lifetime: construction, operation and decommissioning.

Construction

- Potential clearing of areas to accommodate any required infrastructure.
- Levelling and contouring of areas within the site to accommodate transport and construction and to direct stormwater from developed areas to the retention pond.
- Construction of water supply and return systems, including Fraser River intake and return, storage, treatment and distribution or raw water supply wells.
- On-site construction and erection of Ethylene Plant equipment and modules (e.g., pipe racks).
- Transportation of construction materials into Prince George and between shops and the construction site within Prince George:
  - Use of CN rail lines and major highways (16 and 97) for transport of materials and infrastructure to the site, as well as transport of equipment and subcomponents to local module fabrication shops within Prince George. The vast majority of shipments will be bulk construction materials and transportable equipment, but some movement of over-sized equipment and modules on rail or highways into Prince George will be required.
  - Delivery of completed modules from fabrication shops and module assembly yards in Prince George to the construction site. This will include a large number of over-sized loads, most of which are expected to originate within the BCR Industrial Site, but some modules may be transported from fabrication shops on the Hart Highway to the site.
  - Additional detail will be provided as the project execution plan is developed further.
- Installation of tie-ins to pre-existing natural gas supply lines, power supply lines (Fortis, BC Hydro), and potable water and sewage systems (City of Prince George).
- Construction of on-site components such as administration buildings, a laboratory, the Ethylene Plant and wastewater and stormwater collection systems.
- Renovation or construction of off-site buildings such as office space (in Prince George) or maintenance shop space.

- WCOL will embark on a strategy to maximize the amount of fabrication that will be completed in and around Prince George. The scale of the Project far exceeds the capacity of local fabrication contractors (by roughly a factor of 10). WCOL plans to maximize the assembly of modules in Prince George, for easier delivery of complete modules to the site. Large numbers of vessels, heat exchangers, pumps, pipe spools, structural steel elements and other components will be manufactured outside Prince George and delivered to the city for assembly. Large, fully assembled modules and equipment will be delivered from fabrication shops within and around Prince George to the site.
- Lodging for construction workers will be assessed. The combined workforce of the Ethylene Project and related ethylene supply chain projects may require a temporary camp to supplement local housing. WCOL will engage in conversations with the Prince George community to determine if the City has the capacity to accommodate personnel housing requirements. Additional detail will be provided as the project execution plan is developed and regional workforce assessments are completed.

Table 2.4: General Outline of Proposed WCOL Construction Activities.

Construction Activity	Timeline
Site Clearing and Site Preparation	Spring 2021 to Fall 2021
Underground Work, Pilings and /Foundations	Spring 2022 to Fall 2022
Module Installation in Field	Fall 2022 to Summer 2023
Mechanical Completion	July 2023

Operation

- Pre-operation commissioning activities, including:
  - Chemical washing of equipment and safe disposal of used chemicals
  - Air blows and steam blows to remove debris from piping
  - Testing of Process Safety Valves (PSV)
  - Inventorying of all systems with hydrocarbon and initial charges of chemicals
  - Additional flaring during the commissioning and operational testing phase of the equipment
- Delivery of liquid ethane from the NGL Separation Plant via the Transfer Line
- Storage of liquid ethane within bullets

- Treatment and processing of ethane within amine treatment system
- Production and refining of ethylene via Pyrolysis Furnace and processing/separation
- Production of ethylene coproducts via coproduct fractionation
- Production of lean fuel gas from Demethanizer overhead
- Distribution of products into respective storage units
- A continuous flame will be present at the flare tip to maintain pilots and incinerate the natural gas purge of the flare system; the pilot and purge are mandatory features for safe operation of a flare. Intermittent flaring events during plant upsets, plant shutdowns, start-ups, and to ensure protection and safe operation of equipment
- Raw water withdrawal from the Fraser River or raw water wells, treatment, and distribution for use in the plant
- Return of treated water to Fraser River
- General treatment and collection of all other water sources on the Project Area (wastewater, stormwater, etc.)
- Delivery of chemicals and consumables to the site by road. Delivery of these materials and other equipment to the Prince George region may be by truck or rail
- Maintenance when and where needed
- Periodic planned plant turnarounds (every 3 to 5 years). A turnaround is a planned regular plant outage (4 to 5 week duration) to allow for regular inspection and maintenance of equipment to ensure continued safe and reliable operation.

Decommissioning

- Removal of differing units/infrastructure within the plant site (re-use and recycling where possible)
- Will go through proper steps and measurements to ensure that the land is usable following the decommissioning of the WCOL Project
- Expected Project lifespan is at least 25 years

2.3.4 Off-site Utilities and Infrastructure Requirements

Table 2.5 summarizes the key Off-site Utilities and the individual components of each. The following sub-sections provide more detail about the key components. Figure 2.3 gives the general location of some of the Off-site Utilities relative to the Project Area.

The site layout is still under development, so Figure 2.3 provides a preliminary layout only. We note particularly the following:

- The distance and routing of the Transfer Line will be determined with stakeholders and once the site for the NGL Extraction Plant is finalized. The distance and routing of the Transfer Line will be a part of the NGL Recovery OGC submission.
- The location of river intake and/or water wells is under development and will be determined following an assessment of the proposed area shown.
- WCOL has obtained an option to purchase the land shown within the pink outline on Figure 2.3
- Alternative land options were considered. See Section 3.1 for details.

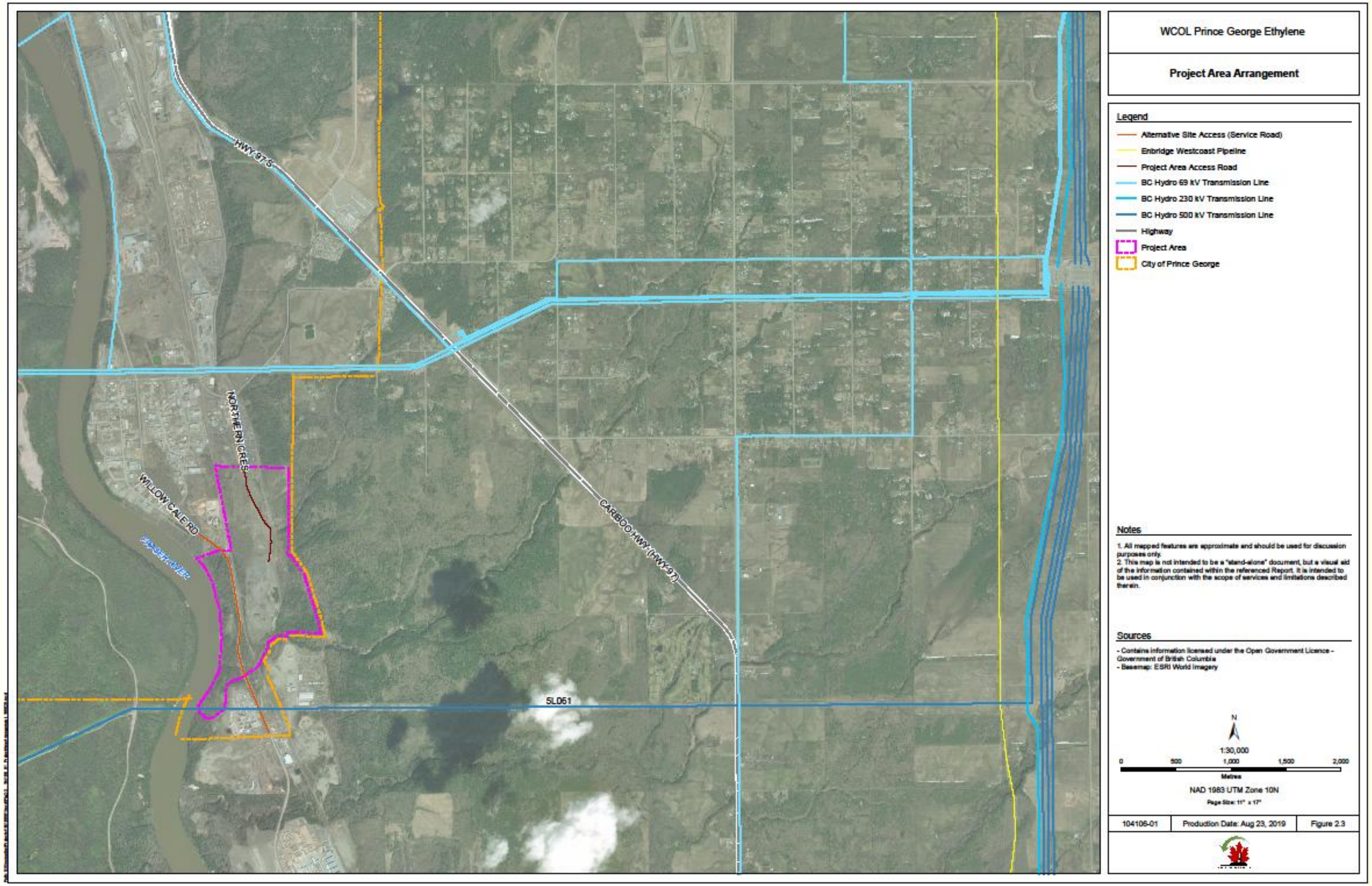

Figure 2.3: Project Area Arrangement.

Table 2.5: Summary of Ethylene Plant Off-site Utilities and Infrastructure.

Key component and Capacity	Individual Components
Electrical Transmission Lines Electricity will be provided to the Ethylene Plant via pre-existing BC Hydro 500 kV transmission lines (BC Hydro, 2017/2018) Additional line could range in length from a minimal tie-in of less than 5 km up to 40 km (iMapBC, 2019)	• Electric Transmission Lines • Transformer • All associated auxiliary equipment
Supporting Infrastructure	• Ethylene Product transfer line • Fuel gas supply line • Access Roads

Electrical Transmission Lines

Electrical power for the Project will be provided via the BC Hydro provincial grid.

Tie-ins to pre-existing 5L061 transmission lines will provide electrical power to the Ethylene Project. These 500 kV lines run adjacent to the WCOL Project Area, approximately 3 km away. A range of less than 5 km up to 40 km of new transmission lines will be completed to allow for tie-in to BC Hydro Power Supply.

Ethylene Project power supply requirement is roughly 12 to 17 MW. Potential to integrate the electrical supply system with the NGL Separation Plant will be considered during detailed design (estimated incremental load of 12 to 16 MW).

Product Transfer Lines

Ethylene product from the Ethylene Plant will be sent via a Transfer Line as feedstock to a third-party Ethylene Derivative Plant and possibly a Mono-ethylene Glycol Plant. The distance and routing of this Transfer Line will depend on the final location of the Derivatives Facility, and its location will be developed jointly between the third-party partner and local stakeholders. The Transfer Line will be sized for anticipated expansion of the WCOL facility and will probably have a capacity of 2 Mt/y.

Access Roads

Willow Cale Road, a forestry service road, runs adjacent to the WCOL Project Area. This gravel road will be used for the transportation of subcomponents and equipment during the construction phases and requires no upgrades to facilitate transportation requirements. There are various access points to the site from Willow Cale Road via the Cariboo Highway, an important factor for minimizing traffic disruptions that may occur during shipping and transportation. Access to the Project Area via Willow Cale is shown in Figure 2.3, which depicts 2 alternative access points.

The main access road for site personnel will be Northern Crescent. No upgrades to Northern Crescent or construction at the access points are anticipated to facilitate transportation needs.

At this time, no new roads are proposed for construction to access the WCOL Project Area for construction or operational use. A logistics study will be performed to identify any upgrades required to the infrastructure (e.g., permanently elevating power lines along the Willow Cale Road).

Rail Loading Facilities

The tank farm (storage area), rail loading area and rail facilities will be owned by the NGL Recovery Project and will be included in the OGC application for that project. Use of the storage area as well as the rail facilities will be provided to the Ethylene Plant as a cost of service from the NGL Separation Plant. Approximately 40 rail cars per week will be loaded with ethylene coproducts. This coproduct will not significantly contribute to the rail traffic that is expected to be produced by the NGL Recovery Project. More information regarding rail loading facilities and relevant statistics is presented in Appendix E.

2.4 Schedules

Table 2.6 presents an estimated schedule of WCOL Project activities. Dates are subject to change, and the duration of each phase will depend on factors such as weather conditions and human resource availability.

Table 2.6: Estimated Timeline for Anticipated Project Milestones.

Project Phase	Project Activity	Timeline
Project Studies	Existing conditions studies	Q3 2019 to Q4 2020
Financial Decision	Final investment decision	End of 2020
Construction	Construction start date	Spring 2021
	Commissioning and start-up	Q2 / Q3 2023
Operations	Facility in-service date	Late 2023
	First shipment of ethylene coproducts from the Ethylene Plant	September 2023
	First shipment of ethylene from Ethylene Plant to Derivative Plant	September 2023
Decommissioning and Abandonment	Decommissioning and reclamation	Upon completion of operation
	Abandonment	Upon completion of reclamation

2.5 Emissions, Discharges and Wastes

As discussed in Section 1, this Project Description specifically pertains to the Environmental Assessment process for the Ethylene Project. Therefore, the following information regarding individual emission points and overall estimated emission values relate to the Ethylene Project only. WCOL will perform cumulative effects assessments on applicable past, present and reasonably foreseeable projects and related Plant components within the agreed study area boundaries (NGL Recovery Plant, Ethylene Plant, and Ethylene Derivitives Plant, as appropriate).

WCOL will report on the Project's emissions in accordance with the *Greenhouse Gas Industrial Reporting and Control Act*, SBC 2014, c. 29, and associated regulations.

2.5.1 Atmospheric Emissions

Operational techniques and modern technology will be implemented within the Ethylene Plant to mitigate air emissions, including but not limited to:

- The use of lean natural gas and Ethylene Plant offgas that consists of mostly hydrogen and methane. These are very clean-burning fuels that emit no odour and minimal particulate matter. They will provide a majority of the fuel requirements within the Ethylene Plant.

- Vapour recovery systems, fugitive emission monitoring systems, and closed sewer systems to minimize fugitive emissions and odours.
- Use of ultra-low NOx burners.

Ethylene Plant Emissions

Anticipated emissions from the Ethylene Plant will arise from various point sources and will comprise carbon monoxide (CO), carbon dioxide (CO_2), hydrocarbons, particulates, sulphur oxides (SOx), nitrogen oxides (NOx), volatile organic compounds (VOC), and water vapour (Table 2.7):

Table 2.7: Ethylene Plant Emission Sources and Types.

Ethylene Plant Emission Point Source	Description	Emission Type	Project Phase
Flare Stack	• The primary purpose of the flare system is to safely deal with emergency releases or abnormal operation (e.g., facility start-up or shutdown). • The emission values calculated are based on the pilot(s) and flare purge gas, which for safety purposes must be in continuous operation to ensure flare safety and readiness.	CO_2 (fired) CO SOx (trace) NOx Hydrocarbons Particulate	O, AM
Pyrolysis Furnace Stacks	• These units mainly utilize hydrogen-rich offgas as the primary fuel source; thus, the amount of natural gas required—and in turn the greenhouse gas emissions—for these furnaces are minimized. • Up to 6 furnaces operate continuously. • Also used to incinerate furnace decoke effluent and CO_2/H_2S vent stream from amine system.	CO_2 (fired) CO SOx (trace) NOx Particulates	O, AM

Ethylene Plant Emission Point Source	Description	Emission Type	Project Phase
Utility Boiler Stacks	• 2 units are used to ensure there is sufficient backup steam available for the Ethylene Plant. • These boilers normally operate at minimum turndown to be ready to supply steam during changing operating conditions.	CO_2 (fired) CO SOx (trace) NOx	O, AM
Vapour Combustion Units	• Present for the incineration of vapour recovered from storage tanks and miscellaneous process vents.	CO_2 (fired) CO (trace) SOx (trace) NOx	O, AM
Amine System (Non-combustion emission source)	• Emissions from this source comprise CO_2 removed from the rich pipeline gas, which is currently being emitted at the point of end users; the WCOL Project does not change the quantity of these emissions. • This stream also contains H_2S and will be sent to the firebox within the Pyrolysis Furnaces for destruction of H_2S and trace hydrocarbons.	CO_2 (unfired) SOx	O, AM

Ethylene Plant Emission Point Source	Description	Emission Type	Project Phase
Pipe Connections and Rotating Equipment Seals	• Small leaks that occur at pipe connections (flanges) and small leaks from pump and compressor seals are the main potential sources of VOC emissions. • The risk of piping leaks will be minimized through the use of welded connections on many hydrocarbon-containing piping in the Ethylene Plant. • Seal systems for the large compressors will be tied into the flare so that hydrocarbon leaks from the seals will be combusted. • The operating facility will have a rigorous VOC monitoring and repair program, which will meet regulatory requirements and industry best practices.	VOC	O, AM
Cooling Tower	• Water loss from the Cooling Tower will be in the form of evaporation and drift (small entrained water droplets).	Water vapour VOC	O

Note:

C – construction; O – operation; D - decommissioning; AM – Accidents and Malfunctions

Additional potential atmospheric emissions from the Ethylene Plant are listed in Table 2.8.

Table 2.8: Potential Project Emissions.

Emission Type	Project Phase
Particulate matter with a diameter of <10 µm (PM_{10})	C, O, D, AM
Particulate matter with a diameter of <2.5 µm ($PM_{2.5}$)	C, O, D, AM
Dust	C, O, D, AM
Carbon monoxide (CO)	C, O, D, AM

Note:

C – construction; O – operation; D – decommissioning; AM – Accidents and Malfunctions

Emissions from the Ethylene Plant are predicted to be up to 0.5 Mt/y for CO_2 (fired) and up to 0.2 Mt/y for CO_2 (unfired), as shown in Table 2.9.

Table 2.9: Estimated Annual Greenhouse Gas Emissions from Ethylene Plant.

Emission Type	Emission Amount
CO_2 (fired)	0.4–0.5 Mt/y
CO_2 (unfired)	0.1–0.2 Mt/y

2.5.2 Wastes, Discharges and Waste Management

Table 2.10 summarizes the potential liquid, solid and hazardous wastes and discharges that may result from the Ethylene Project, together with the sources of these wastes and discharges and potential waste management strategies.

With the implementation of waste management strategies and the utilization of appropriate treatment and disposal facilities, WCOL will reduce both the amount and potential impacts of waste.

Table 2.10: Potential Wastes and Discharges from the Ethylene Project.

Potential Waste or Discharge and Source	Proposed Management or Mitigation	Project Phase
Liquids		
Discharges from process operation (Cooling Tower blowdown, and demineralization regeneration stream)	• Cooling tower blowdown will be combined with the demineralized water regeneration stream. • Regeneration of the demineralized water treatment process (ionic exchange) will result in a regeneration stream containing a high mineral content. • The combined stream will be cooled and returned to the Fraser River. The volume will be much less than the original raw water make-up, but it will contain most of the dissolved salts and minerals that were in the original water intake. The amount of blowdown and the mineral content of the blowdown will be dependent on the quality of the raw water make-up (river water and well water quality varies). • The stream will be treated and pH adjusted as required, and water quality will comply with permit conditions when discharged.	O
Stormwater	• Stormwater will be collected on site in a retention pond, treated (if required) and used as a cooling water make-up for the Cooling Tower. Recycling of the stormwater will reduce the amount of raw water make-up required. • Any stormwater not used as cooling water will be tested, and water quality will comply with permit conditions before the water is discharged.	C, O, D
Segregated collection system wastes	• Liquids from any of the segregated collection systems (amine sump, caustic sump, closed hydrocarbon drain, chemical collection sumps) may not be suitable for recycling, in which case they will be trucked off site for appropriate disposal.	O
Spent liquids from lab (e.g., used solvents)	• Follow proper Workplace Hazardous Materials Information System procedures and Material Safety Data Sheet procedures for disposal methods.	O

Potential Waste or Discharge and Source	Proposed Management or Mitigation	Project Phase
Used potable or utility water	• Potable or uncontaminated utility water wastes will be directed into a sewer system that connects with the City of Prince George water treatment facilities and discharge routes. This sewer line will be completely segregated to ensure no water from the processing facility can become mixed with this stream.	C, O, D
Spent hydrostatic water from testing procedures	• Used water will be collected onsite and will be treated and pH adjusted as required. Water quality will comply with permit conditions when discharged.	O
Waste caustic	• Will be transported from site and disposed of at appropriate facility.	O
Spent chemicals such as glycol or amine	• Chemicals that need to be replaced will be trucked offsite to be disposed of at suitable facilities.	O
Discharge that results from maintenance of Quench Tower (coke, tar, oil)	• Materials will be shipped offsite for disposal at suitable facilities. Can be a combination of liquids and solids.	O
Non-recyclable streams resulting from waste water treatment, such as non-separable oil/water streams	• Wastes will be shipped offsite for disposal at suitable facilities.	O, AM
Chemical spills on site	• Collect spill and dispose of chemical suitably.	AM
Liquid hydrocarbon spill or leak within secondary containment	• Recover hydrocarbon and reprocess or suitably dispose if contaminated.	AM
Liquid hydrocarbon spill outside of secondary containment	• Outside of secondary containment, liquid hydrocarbon will flow to stormwater retention pond. Will recover hydrocarbon and treat contaminated water within pond.	AM
Pressurized hydrocarbon leak at flanges, pump seals or instrument connections	• Will be recovered within containment, reprocessed or suitably disposed of if contaminated.	AM
Release of glycol as a result of break in glycol tracing system	• Use of absorbent to collect spilled materials, and suitable disposal of contaminated materials.	AM

Potential Waste or Discharge and Source	Proposed Management or Mitigation	Project Phase
Gases		
Pressurized hydrocarbon leak at flanges, compressor seals or instrument connections	• Major leaks will result in a hydrocarbon release to atmosphere. Gas leak detection systems will be installed throughout the facility with alarms to alert operators to isolate leaking equipment and shutdown the plant if necessary.	AM
Flaring of residual hydrocarbons to de-inventory equipment for preparation of equipment maintenance and inspection during turnaround	• Operating procedures will be developed to recover as much hydrocarbon inventory as possible prior to starting the de-inventory process.	O
Solids		
Solid residue resulting from the raw water treatment process	• The disposal method for this waste is still being determined. It may be sent to landfill.	O
Wastes that may result from on-site construction of equipment or modules and future in-plant projects (metal scraps, piping, packaging, etc.), and waste safety consumables, such as gloves or disposable coveralls	• Segregate and recycle if possible and dispose of remaining material at proper facility.	C, O, D
Vegetation and biomass resulting from any levelling or clearing of land that needs to occur during construction	• Will be stockpiled on site and re-used or sold as fibre to local wood processing facilities where possible. Excess vegetation will be disposed of per City of Prince George requirements and facilities. Any contaminated material will be removed and disposed of offsite in an approved facility.	C, D
Domestic wastes (food wrappers, cardboard, plastics, etc.)	• Recycle if possible and dispose of remaining material at a proper facility.	C, O, D
Materials that cannot be re-used or recycled following decommissioning of the Project	• Dispose of at a designated landfill or other facility.	D

Potential Waste or Discharge and Source	Proposed Management or Mitigation	Project Phase
Used solid filter media (e.g., water treatment sand / anthracite, quench water walnut shells, activated carbon from amine filters)	• Recycle or dispose at a designated landfill or other facility, as appropriate.	O, D
Used filter cartridges	• Dispose of at proper facility.	O, D
Used drier molecular sieve	• Recycle or disposal methods to be confirmed.	O, D
Spent Acetylene Reactor catalyst	• Typically sent to original catalyst vendor for recycling of precious metals in the catalyst.	O, D
Used tubes/coils from the Pyrolysis Furnace	• Furnace tubes have high nickel and chrome content, so materials are typically sold to metal dealers to recover and recycle the valuable metals.	O
Hazardous Wastes		
Used furnace refractory	• Requires special handling and disposal to contain fibres that can be released from brittle refractory after it has been in service.	O, D
NORM (naturally occurring radioactive materials) contaminated wastes	• Requires special testing, handling and disposal, following published guidelines and standards for NORM materials.	O, D
Accidental release of motor oils or hydraulic oils from construction equipment	• Disposal of contaminated materials (e.g., cleaning supplies) at designated facilities.	C, D, AM

Note: C – construction; O – operation; D – decommissioning; AM – Accidents and Malfunctions

2.6 Ethylene Plant Design and Operations Features for Environmental Performance

Ethylene manufacturing is a very mature industry and designs have evolved to continuously improve the utilization of feedstock, the consumption of fuel and the environmental performance of ethylene plants. Ethylene can be manufactured from a range of feedstocks and ethane is the most direct and energy efficient feed to use to deliver ethylene as the primary product. The Ethylene Plant design will benefit from the constant technological evolution of plant and equipment design improvements within the industry and consequently the WCOL Ethylene Plant will have best in class energy and environmental performance. This section outlines the multitude of heat integration and recycling design features and equipment and process operations advances that will result in improved efficiencies environmental performance within the Ethylene Plant.

2.6.1 Energy Efficiency within the Ethylene Plant

High energy efficiency within the Ethylene Plant is a function of two primary aspects in the design: pyrolysis furnace design features and overall plant energy integration.

The heart of the proprietary technology associated with an ethylene plant design is the pyrolysis furnaces. The reaction from ethane to ethylene takes place in the radiant coils and the furnaces are the single largest energy consumer within the ethylene manufacturing process. The Pyrolysis Furnaces will be designed with short residence time coils (typically <0.6 seconds) and a proprietary effluent quench exchanger design, which combine to deliver an ethylene yield of approximately 80%. A higher yield reduces the amount of energy required to separate and recycle undesired byproducts, and therefore results in higher energy efficiency.

Further, the Pyrolysis Furnaces will have a high degree of energy efficiency, with an expected thermal efficiency of 90% to 94%. This is accomplished by investing capital cost in the furnaces and related equipment to maximize energy efficiency:

- Heat is recovered from the hot furnace effluent by generating very high pressure (VHP) steam in the effluent quench exchangers and then also to preheat boiler feed water.
- Heat from the combustion flue gas in the furnaces will act as a heating medium to preheat ethane and dilution steam feed as well as the boiler feed water and also to superheat VHP steam.
- Combustion air will be preheated with available waste heat, reducing the heat input required to the furnaces.

Ethylene manufacturing processes are highly energy integrated and have evolved significantly in the last 20 to 30 years, with technology licensors reporting reductions in energy consumption in the range of 30%. In addition to the furnace design features listed above, this has been largely achieved through optimization of the ethylene separation and recovery equipment to reduce the compression horsepower required. The Ethylene Plant will also produce and use VHP steam, which results in greater efficiency in the generation and utilization of steam throughout the plant.

2.6.2 Low Carbon Footprint and Atmospheric Emissions

The Ethylene Plant will produce over 200 t/d of hydrogen as a byproduct, which has many potentially advantageous uses environmentally. The WCOL Ethylene Plant will use this produced hydrogen (part of the offgas produced by the plant) as the primary fuel source for the Pyrolysis Furnaces. When this fuel (offgas) is burned, emissions will be mainly water vapour and CO_2, resulting in a small GHG footprint for the facility.

Furthermore, the furnaces will be equipped with ultra-low nitrogen oxide (NOx) burners that are expected to emit less than 0.065 pounds of NOx per million Btus of heat produced (<0.065 lb/MBtu of NOx).

Finally, radiant coil technology improvements, specifically surface technology, reduce the amount of coke that forms within the furnace coils. As a result, the decoking process will be less frequent, thus reducing the associated emissions. This also translates into longer furnace run times which results in more efficient use of resources.

2.6.3 Technical and Environmental Advances Inherent within Ethylene Plants

There are numerous other plant design and specific equipment advances which reduce energy consumption and emissions and improve overall environmental performance:

- Acetylene Reactor technology, specifically catalyst surface technology, has been improved to increase selectivity, thus preventing over-conversion of ethylene to ethane and optimizing the use of ethane feedstock.
- The use of steam for all major compressor drivers will eliminate the need for electric or gas-based drivers, and will thus reduce the amount of atmospheric emissions.
- Use of steam to supply process heat will eliminate the need for a separate fired process heat medium system.
- The Ethylene Plant will have low-flaring start-up procedures and the plant will be designed with the necessary recycle streams required to accommodate these procedures. Low-flaring startup procedures will lead to minimized flaring requirements during abnormal operation, and thus the reduction of potential atmospheric emissions.
- Ethylene plants are inherently very reliable, with typical onstream time of >98%. Longer onstream times will reduce plant upsets, flaring time, the potential for safety incidents and lost productivity.

- Major compressors within the facility are expected to have efficiencies of between 81 and 87%, reducing the energy required.
- Advanced process control systems will be installed by the Project and will be developed over the life of the plant to optimize plant productivity and minimize the energy requirements within the plant. They will be automated systems that operate 24 hours per day, 7 days per week.

2.6.4 Minimization of Water Use

The Project will integrate various strategies to minimize water withdrawal from raw water sources.

Firstly, the Cooling Tower is a circulating system, providing non-contact cooling of the process. Treatment of the make-up to the cooling water system combined with a chemical treatment program allows the system to be operated at typically 8 to 12 cycles of concentration, to significantly reduce the raw water make-up requirements for the Project. Additional improvements, such as the drift eliminator systems, will reduce the amount of water losses from the system.

Internal water recycling strategies have been identified for the Ethylene Plant and will minimize the volume of water make-up required. Quench water treatment systems will separate hydrocarbons (often referred to as oils) from water that has condensed from pyrolysis gas effluent. The reclaimed water will be re-used as dilution steam make-up. Blowdown streams from the dilution steam system and steam system will be also recycled as make-up to various processes within the Ethylene Plant.

Miscellaneous process wastewater streams within the Ethylene Plant will also undergo internal treatment and be recycled where possible. Further, the proposed recycling and re-use of captured stormwater will further reduce raw water make-up requirements.

2.7 Project Capital Costs and Employment

All estimates in this section related to capital and operating costs and employment opportunities (both construction and long-term operations) are based on preliminary estimates and will be refined as the design of the Project is advanced and detailed project execution plans and operations establishment plans are developed. Updated information will be provided in the Application.

The capital cost of the Ethylene Plant and associated utilities and infrastructure, as described in this Project Description, is estimated at $2 billion to $2.8 billion. WCOL is developing a project execution strategy that focuses on maximum modular construction in fabrication shops and modularization yards in order to minimize the size of the site construction force and to control Project capital costs. This approach will shift some construction personnel from the on-site field construction force to larger numbers of construction workers located in fabrication and module assembly shops. WCOL is also working with local Prince George contractors to maximize the use of local fabrication and construction companies. This strategy will result in a large construction workforce to support the Project, located in the Prince George region, but will distribute the workforce between the facility construction site and local fabrication facilities, making the estimate of peak construction personnel loading difficult to determine until a detailed execution plan is finalized. WCOL expects local site construction and fabrication activities to span from the spring of 2021 through the summer of 2023. During this period, the workforce dedicated to Project fabrication and construction activities is expected to peak at between 2,000 and 3,000 workers.

Annual operating costs for the facility are estimated to be roughly Cdn $60 million, including salaries, chemicals, insurance, maintenance materials, utility costs, and other costs, but excluding the cost of ethane feed sold to the Ethylene Plant. Long-term employment numbers associated with operation of the Ethylene Plant are expected to be between 140 and 180 permanent, direct employees. The facility will also engage approximately 25 to 50 contract employees to support operations and maintenance activities. Permanent positions required for the long-term operation of the facility are expected to have annual salaries ranging from $60,000 to $150,000, with an average salary of around $100,000. Many of these positions are highly skilled and require specialized training. The facility will also have annual sustaining capital expenditures to cover required regular maintenance, inspections and periodic upgrades to ensure the on-going safe and reliable operation of the equipment. This sustaining capital typically requires annual spending in the range of 1 to 2% of the original capital cost of the facility and is expected to vary between Cdn $20 million and Cdn $50 million each year.

3 Project Location and Land and Water Use

This section describes the proposed location of the WCOL Project Area, as well as land use designation, water use and zoning on and around the Project Area. Indigenous communities affected by the Project are also considered and discussed. For further information regarding land and water use in a socioeconomic setting, refer to Section 4.2.2.

3.1 Overview

The Project location has been selected to be on previously developed, fee simple land within the Prince George BCR Industrial Area. This location has been selected to minimize impacts on Indigenous groups and the broader community.

WCOL has selected the region of Prince George as the optimum location for the Project because this region offers the following advantages:

- The Westcoast Pipeline is located within 10 km to the east of the City. Use of natural gas from this pipeline will eliminate the need for the construction of any new major pipeline infrastructure.
- The routes for proposed liquefied natural gas pipelines all pass within roughly 100 km north of Prince George, providing access to future natural gas liquids.
- Prince George is a main hub for CN Rail, with connectivity to ports in Prince Rupert, Kitimat and Vancouver for export of products.
- BC Hydro has a major north-south transmission line that runs to the east of Prince George, which will provide the Project with access to green, high-voltage power supply from the new Site C dam.
- The Fraser River is one of the largest rivers in western Canada, providing ample water supply to meet cooling water and steam requirements.
- The population of the City is roughly 75,000 and the immediate region exceeds 100,000, with a labour force that is expected to provide the employment base necessary to support a major manufacturing facility.
- Prince George has had a history of industrial activity in the forestry sector. The population is supportive of resource development and value-add industries.

The proposed Project Area location is approximately 12 km south of the Prince George city centre and 8 km south-west of the Prince George airport. The closest residence to the site is approximately 1.5 km to the northeast.

Alternative site locations were considered, but the other locations did not meet all the requirements of the Ethylene Project or had specific drawbacks relative to the proposed site. More detail regarding these options will be discussed within future application documentation. The Project Area has been selected for the following reasons:

- It was previously developed for industrial uses (for log storage and use as a gravel pit), minimizing the Project's impact on undisturbed land.
- It provides direct access to the CN rail line with no new rail lines or spurs required.
- It lies adjacent to, and provides access to, the Fraser River.
- Close proximity to high voltage power lines.
- Close proximity to the Westcoast Pipeline.
- Adjacent to the majority of Prince George's fabrication facilities, providing the opportunity to have module assembly completed close to the construction site, thereby minimizing the amount of module transportation required.
- Within the City limits, reducing the distance of travel required by the majority of the workforce and minimizing travel-related risks for personnel over the life of the Project.

The Project Area is within the Regional District of Fraser-Fort George (RDFFG), which is comprised of 4 municipalities (including Prince George) and 7 electoral areas (Regional District of Fraser-Fort George, 2019).

The Project Area is located on fee-simple land within the city limits of Prince George and falls within the Traditional Territory of the Lheidli T'enneh Nation. The potential impacts of the Project on Aboriginal and treaty rights, and the interests of Lheidli T'enneh Nation and other Indigenous groups will be considered by WCOL as part of the Application.

3.2 Land Ownership and Legal Description

The WCOL Project Area is comprised of 2 private land parcels in the BCR Industrial Site, located within the Prince George city limits. The land titles and ownership for the proposed Project Area, as well as the land immediately adjacent, is depicted in Figure 3.1. Legal descriptions and information regarding these land parcels are presented in Table 3.1 and Table 3.2.

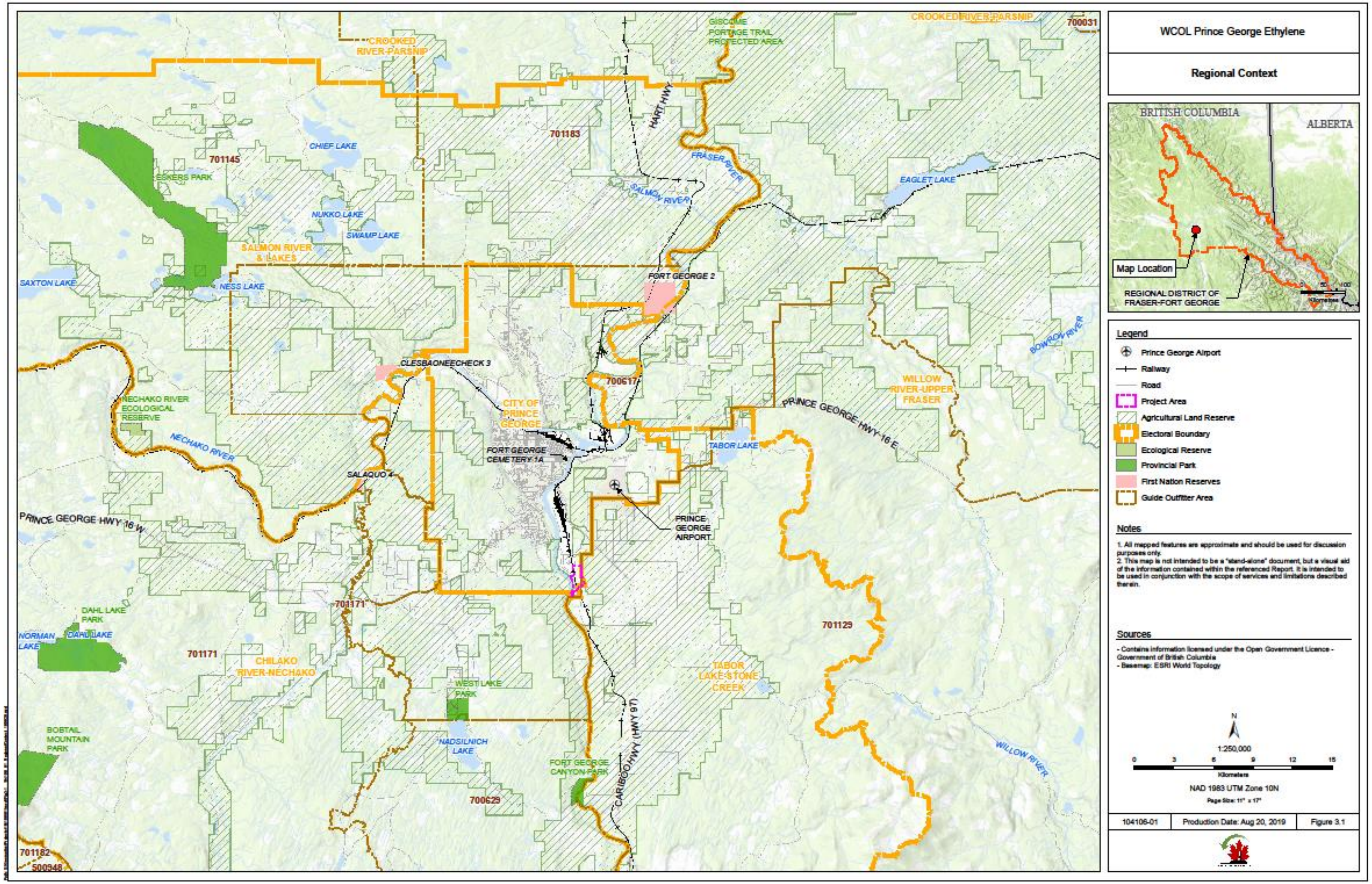

Figure 3.1: Land Titles and Ownership of Project Area and Surrounding Land.

Table 3.1: WCOL Project Area Description and Ownership.

Site Owner/Administrator	596848 BC Ltd. WCOL option to purchase
Site Location	Prince George, BC
Approximate Geographic Coordinates	53°49'27.5"N; 122°43'29.5"W
Proposed Project Area	The total Project Area is approximately 120 hectares. The Ethylene Plant will occupy only a portion of the total site

Table 3.2: Legal Description of WCOL Project Area.

Parcel ID	Type	Owner/Administrator	Legal Description
027-985-032	Fee Simple	Private	Lot 1 Plan BCP41694 District Lot 752 Land District 05 and DL 1565, 1566
014-996-952	Fee Simple	Private	Part 1 SE District Lot 751 Land District 05 LYING E OF PL A227

(PGMap, 2019) (ParcelMap BC, 2019) (BC Assessment, 2019)

The Project Area is located within an under-utilized, existing industrial park. The northern portion of the Project Area was previously used as a log storage yard. The southern parcel was later used as a gravel pit.

3.3 Water Use

The following sections describe anticipated water usage by the Ethylene Project, as well as pre-existing water users and licences that exist on or around the Project Area location.

3.3.1 WCOL Water Use

Table 3.3 summarizes the water requirements and water distribution throughout the Ethylene Plant. As the largest consumer of water within the WCOL Development, the Ethylene Plant will be the water licence holder. The Ethylene Plant will provide wastewater handling, and treated water will be sold to the NGL Separation Plant as a service to meet water requirements.

Table 3.3: Water Usage and Distribution in the Ethylene Plant.

Water Usage Component	Water Diversion and Use
Raw Water Withdrawal and Treatment Raw water supply between 600 and 650 m^3/h of to meet water requirements for the Ethylene Plant.	• Water will be withdrawn from either the Fraser River or from ground water wells, or a combination of the two, and treated to meet the various process requirements. • Raw water will be treated as required to remove suspended solids, hardness, etc., making it suitable for make-up to the cooling water system.
Cooling Tower The Cooling Tower will circulate between 25,000 and 35,000 m^3/h of cooling water to the Ethylene Plant. It will rejecting up to 1,500 GJ/h of heat via evaporation.	• Following adequate treatment, cooling water make-up will be fed to the Cooling Tower. • Water losses from the Cooling Tower will primarily be from evaporation, as well as a minor amount of drift (entrained water droplets). • Evaporation will cause the concentration of dissolved minerals, such as calcium, to increase within the circulating cooling water stream. • Thus, to prevent mineral deposition on heat exchangers in the facility, a small blowdown stream will be withdrawn from the circulating cooling water to maintain acceptable mineral content in the system. • Treated river water will be continuously used as make-up to the cooling water system to replace these losses.
Ethylene Plant Cooling Water	• Non-contact cooling water will be continuously circulated to the Ethylene Plant and passed through heat exchangers to remove heat from the ethylene production process. • The warm cooling water will be returned and cooled by direct contact with ambient air in the Cooling Tower.

Water Usage Component	Water Diversion and Use
Boiler Feedwater Make-up	• Treated water will be further treated to remove hardness and other contaminants to meet stringent boiler feedwater requirements. This treatment is expected to include ion exchange beds. Regeneration of ion exchange beds will result in a water stream that will be returned to the river. • Make-up water will be continuously added to the steam system to replace the blowdown and losses. • Make-up water will be continuously added to the dilution steam system. • Minor amounts of treated water will be required as make-up to the Ethylene Plant amine system.
Steam System The steam system will have the capacity to produce roughly 450 t/h of VHP steam.	• High-pressure steam will be generated from waste heat in the Ethylene Plant and used to power steam turbine drivers and provide process heat to heat exchangers throughout the ethylene production process. • The majority of the steam will be condensed and recycled (minimal losses), but a small blowdown stream (1 to 2% of total steam production) will be continuously removed from the steam system to prevent hardness concentrations from cycling up and causing damaging deposits to occuring the boiler tubes or heat exchange equipment. • Blowdown will likely be recycled to the Quench Water system for re-use.

Water Usage Component	Water Diversion and Use
Water Effluent to River The Ethylene Plant will discharge between 70 and 120 m^3/h of combined blowdown from various process operations.	• Cooling Tower blowdown and demineralized water treatment regeneration streams will be combined. • These streams will have elevated mineral levels as dissolved solids from the fresh river water withdrawal becomes concentrated in this stream. This combined blowdown stream will be treated and cooled to meet the requirements of the environmental discharge permits prior to being returned to the Fraser River.
Dilution Steam System	• Dilution steam will be added to ethane feed to reduce coking rates in the Pyrolysis Furnaces. • Water present in the Pyrolysis Furnace effluent will condense within the upper portions of the Quench Tower (quench water). • The quench water will undergo treatment to remove heavy C5+ hydrocarbons and then will undergo stripping to remove light hydrocarbons and be subsequently used to generate dilution steam. This closed system will maximize water re-use. • Trace amounts of dissolved hydrocarbons that exist within the treated quench water can cause buildup during dilution steam production; thus, a blowdown stream will be withdrawn. • The blowdown will likely be recycled as cooling water make-up.

Water Usage Component	Water Diversion and Use
Utility and Potable Water	• Clean, filtered utility water will be required for various minor consumers, such as pump seal flushes. Most of this water will be recovered from the process and recycled. • Potable water will be provided for various operations of the plant, including but not limited to eye washing stations, emergency showers, kitchen, and lavatory uses. • Potable and utility water will be supplied from the Prince George municipal water supply. • Sanitary sewer collection will be included where required, and sanitary sewage/water will be collected and sent to the Prince George sewage collection system. • No process water will be tied into the city sewage system.

3.3.2 Current Water Use in the Project Area

The only non-Project water uses within the WCOL Project Area are 2 water wells (Well Tag Numbers 56895 and 74538) (iMapBC, 2019). It is not yet known if process water for the Ethylene Plant will be withdrawn from these wells.

Additionally, no previous water licences exist within the Project Area. There is one water licence approximately 4 km downstream from the Project Area that withdraws from the Fraser River. This licence is for placer mining purposes and is for 0.005 m^3/s (iMapBC, 2019). This licence is not affiliated with the WCOL Project and will not be affected by the Project.

3.4 First Nations Reserves and Indigenous Traditional Territories

A search of the provincial Consultative Areas Database identified that all construction activities associated with the Project will be within the Traditional Territory of the Lheidli T'enneh First Nation (Government of BC, 2019). The Nazko First Nation is another Indigenous group that has a claimed territory that lies on the west side of the Fraser River, across from the Project Area for the Ethylene Plant.

The Project Area, the City of Prince George and the surrounding region are within the Traditional Territory of the Lheidli T'enneh First Nation (Lheidli T'enneh n.d.). Project activities and components therefore have the potential to directly interact with the rights and interests, uses and activities of the Lheidli T'enneh First Nation.

There are 4 Lheidli T'enneh reserves. The closest Lheidli T'enneh reserve is approximately 8 km north of the Project Area (PGMaps) and comprises the Fort George Cemetery 1A (iMap BC), which lies within the Prince George city limits. All other Lheidli T'enneh First Nation reserve lands are located outside the Prince George city limits. Table 3.4 illustrates the land use designation of the reserve lands as described in the Lheidli T'enneh First Nation Land Use Plan (Lheidli T'enneh 2017).

Table 3.4: Overview of Lheidli T'enneh First Nation Reserve Land.

First Nation	Reserve Number and Name	Proximity to WCOL Main Site	Land Use Designation
Lheidli T'enneh	IR #1 Ts'unk'ut – Lheidli T'enneh Cemetery(Fort George 1)	Approximately 8 km north of WCOL Project Area (within Prince George city limits)	• Cultural/Heritage Site for Lheidli T'enneh First Nation
Lheidli T'enneh	IR #2 Khast'an Lhughel – North and South Shelley (Fort George 2)	Approximately 14 km northeast of Project Area	• Community Development • Industrial • Agriculture and Resource • Cultural
Lheidli T'enneh	IR #3 Lhezbaonichek – Clesbaoneecheck	Approximately 18 km northwest of Project Area	• Community Development • Agriculture and Resource
Lheidli T'enneh	IR #4 Dzulhyazchun Tsalakoh – Salaquo	Approximately 15 km northwest of Project Area	• Agriculture and Resource • Heritage/Cultural

(iMapBC, 2019), (Lheidli T'enneh Lands Authority, 2017)

The Nazko First Nation administrative centre is located in Nazko, 112 km west of Quesnel. The Nazko First Nation Statement of Interest identifies the Nazko Traditional Territory as extending from Quesnel to Prince George (BC Treaty Commission 2019). The Statement of Interest does not overlap with the Project site; however, Project activities have the potential to indirectly interact with the rights and interests of Nazko First Nation, for example by interacting with air or water resources.

Figure 3.2 depicts the Traditional Territories of Indigenous Groups relative to the Project Area.

See Section 5.1 for additional considerations related to Indigenous groups.

3.5 Land Use Plans

The land use and land designations associated with the Project Area land parcels and the surrounding locations are discussed in the following section.

3.5.1 Land and Resource Management Plan and Provincial Land Designation

The Project Area resides within the Settlement and Agriculture resource management zone, as stated in the Land and Resource Management Plan. This plan outlines land use and resource development strategies on Crown land, defined within the plan area (City of Prince George , 1999). However, because the Project Area land parcels are designated as private, the plan is not applicable (City of Prince George , 1999).

The eastern portion of the Project Area is within the Agricultural Land Reserve (ALR). The ALR is a zone defined by the Provincial Agricultural Land Commission wherein agriculture is recognized as the priority use (Government of BC, 2014). Further information regarding the ALR is addressed within Section 3.5.3.

3.5.2 Prince George Official Community Plan

The WCOL Project Area falls under the City of Prince George Official Community Plan (OCP), a document that lays out objectives and policies regarding land use and development within the city. The proposed WCOL Project aligns with many of the overall objectives presented in this document, including those presented in Table 3.5.

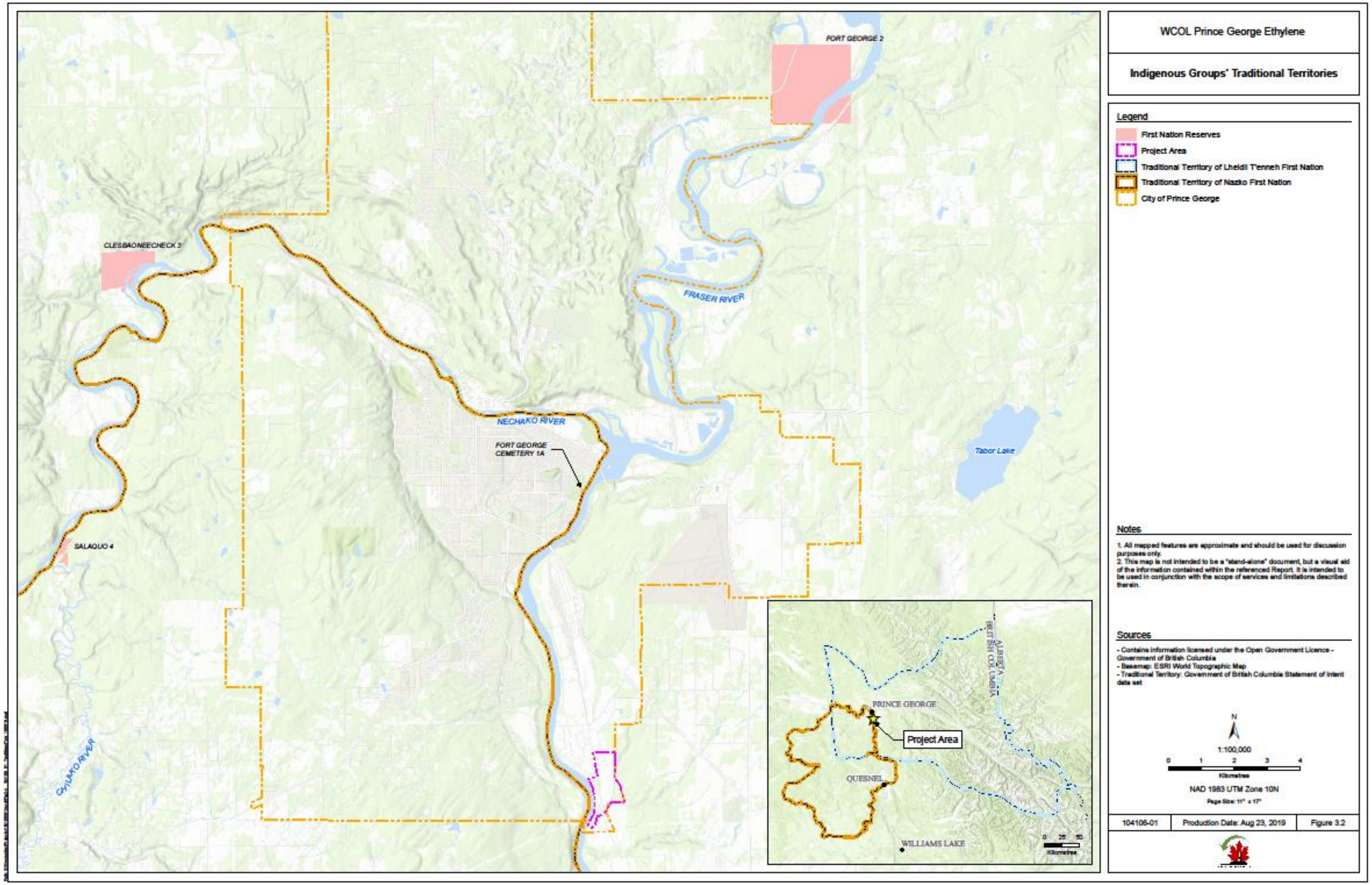

Figure 3.2: Indigenous Groups' Traditional Territories Relative to Project Area .

Table 3.5: Alignment between City of Prince George OCP Overall Objectives and WCOL Project.

OCP Objective	WCOL Project Alignment
Objective 5.1.5 – Support institutions that enhance our knowledge-based economy such as University of Northern British Columbia (UNBC), College of New Caledonia (CNC), and commercial and trades training opportunities.	• Numerous indirect benefits will be associated with the Project, including training at local institutions (UNBC and CNC). • Many of the positions created by the Project will be highly skilled and require specialized training.
Objective 5.1.6 – Support the Growth Management strategy by matching employment growth with population growth.	• During the construction period of the Project, the workforce is expected to peak between 2,000 and 3,000. • Long-term employment is expected to include between 140 and 180 permanent employees. • To support maintenance and operation activities, the Project is expected to engage between 25 and 50 contract employees.

(City of Prince George , 2012)

The development also aligns with many of the OCP's industrial-sector objectives, including those listed in Table 3.6.

Table 3.6: Alignment between City of Prince George OCP General Industrial Objectives and WCOL Project.

OCP Objective	WCOL Project Alignment
Objective 8.3.20 – Minimize impacts on adjacent areas.	• The proposed Project Area location is a previously developed site. Little additional disruption of the surrounding area is likely to occur during construction phases. • Given the Project Area's proximity to existing amenities and utilities, additional construction of adequate tie-ins will be minimized.

OCP Objective	WCOL Project Alignment
Objective 8.3.22 – Encourage use of currently serviced land and existing amenities such as transit access, road networks, rail lines, and utilities	• Access to the site will be via existing transport and access roads (Willow Cale Road and Northern Crescent). At this time no need for access road construction or maintenance is anticipated before Project phases begin. • Existing CN Rail tracks will be used for product loading and transport, and less than 20 km of track needs to be developed to accommodate rail loading facilities for products and coproducts. Note that rail is not directly within the Project scope of this EA. • Secondary BC Hydro Transmission lines run adjacent to plant, and new transmission lines to be developed for tie-in purposes are anticipated to range between less than 5 km up to 40 km).

(City of Prince George , 2012)

To ensure alignment with OCP Future Land Use, WCOL has reviewed future development permit areas (Schedules D1-D5) and determined the following:

- Based on Schedule D-1, there exists a groundwater protection area north of the Project Area, but none on or immediately adjacent to the Project Area itself (City of Prince George , 2011).
- From Schedule D-2, the Project Area encompasses areas identified as a Riparian Protection Development Permit Area. These zones encompass the Fraser River (bordering the western portion of the Project Area) and Haggith Creek, which runs through the Project Area. These zones will be further discussed in Section 3.5.3. (City of Prince George , 2014).
- The Project Area is not classified as a Wildfire Hazard area, based on Schedule D-3. There is a hazard area located approximately 1 km northwest of the Project Area. The Ethylene Project will be fitted with appropriate fire protection (City of Prince George , 2011).
- The western border of the Project Area (that which borders the Fraser River) is classified as a flood hazard area based on Schedule D-4 (City of Prince George , 2011).
- Based on Schedule D-5, the Project Area does not exist close to Intensive Residential Development areas (City of Prince George, 2014).

- Based on the City of Prince George's Active Transportation Plan, shared bike lanes exist on the roads surrounding the Project Area, including Sinnich Road and Penn Road. However, none extend into the Project Area Location.

Future land use designations as outlined by the OCP, together with WCOL's alignment plan, are further discussed in Section 3.5.3.

Within the city limits of Prince George, there exist no provincial parks, eco-reserves, or protected areas (iMapBC, 2019). The closest protected parks/lands are Fort George Canyon Provincial park (approximately19 km south of Prince George) and West Lake Provincial Park (approximately 14 km southwest of Prince George) (iMapBC, 2019). As previously mentioned, the Fraser River, which borders the western portion of the Project Area, and Haggith Creek, which intersects portions of the Project Area, are identified as Riparian Protection Development Permit Areas.

Prince George features a multitude of municipal parks, but none exist close to the Project Area; the nearest Park is Parkridge Creek Park, which is approximately 2 km northwest of the Project Area. To the north of the Project Area lies an area of land which is designated as an Open Space based on Green Belt classification (City of Prince George, 2016).

Figure 3.3 depicts the Project Area relative to regional land designations, including First Nation's Reserves and Provincial Parks.

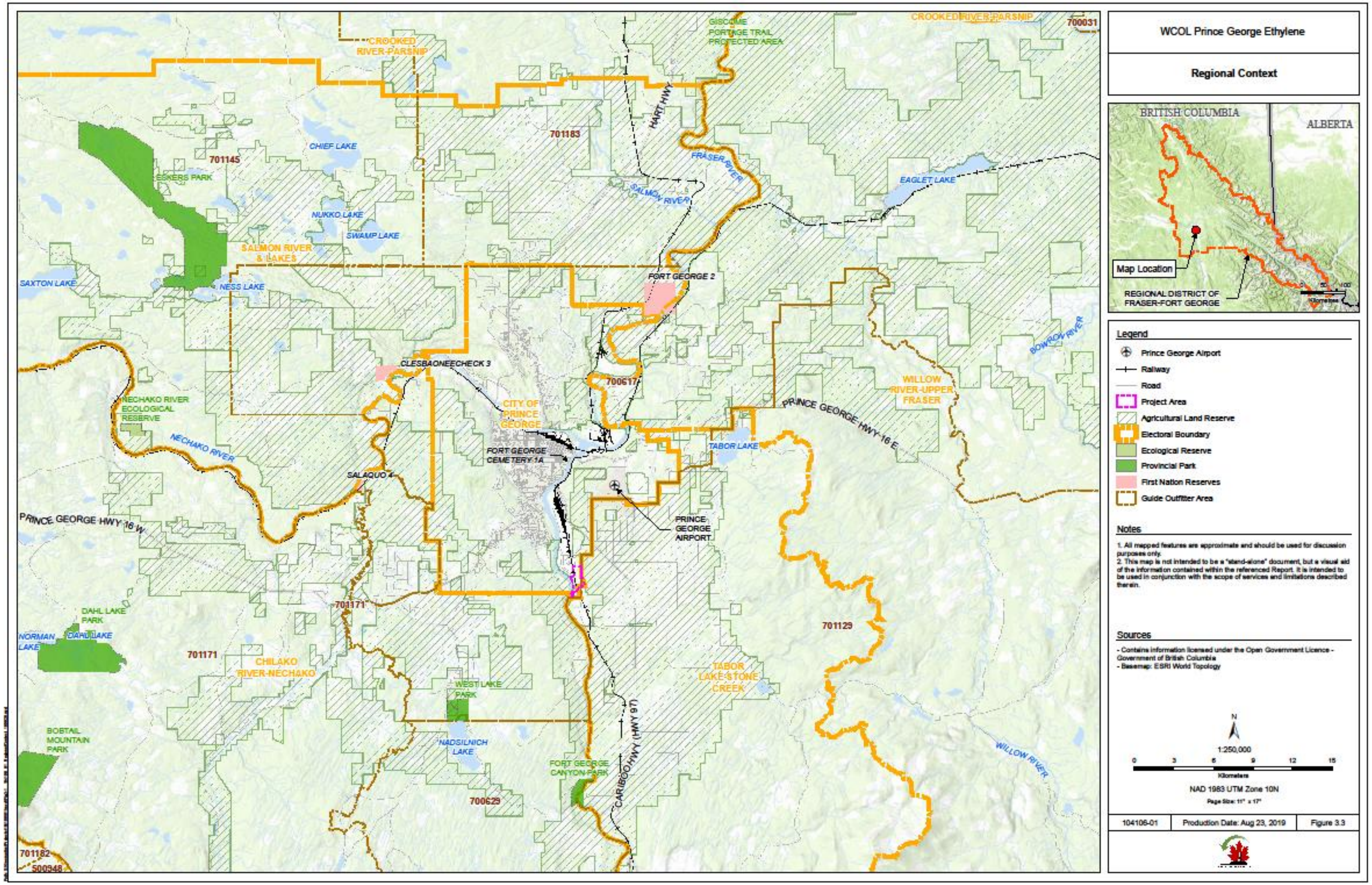

Figure 3.3: Project Area Relative to Regional Land Designations.

3.5.3 Rezoning under the OCP

PID: 014-996-952 (Northern Parcel)

Based on OCP Future Land Use, depicted within Figure 3.4, the parcel of land on which the Project is proposed is designated as:

- Business District, Medium Industrial
- Rural Resource (City of Prince George, 2018)

To accommodate the proposed facility on site, WCOL will submit an OCP Amendment application to re-designate the property to:

- Business District, Heavy Industrial (City of Prince George, 2018)

Zoning information is summarized below, and depicted within Figure 3.5.

Table 3.7: Zoning Information for WCOL Northern Parcel.

Parcel ID	Current Zoning	Required Rezoning
014-996-952	• AG (Green Belt) • AF (Agriculture and Forestry)	• M6: Special Heavy Industrial

(PGMap, 2019)

PID: 027-985-032 (Southern Parcel)

Current OCP designations, depicted in Figure 3.4, define this parcel of land as:

- Business District, Light Industrial
- Business District, Medium Industrial
- Rural Resource (City of Prince George, 2018)

To accommodate the proposed facility on site, WCOL will submit an OCP Amendment application to re-designate the property to:

- Business District, Heavy Industrial
- Utility
- Rural Resource (City of Prince George, 2018)

Zoning information for this parcel is presented in Table 3.8 below, and depicted in Figure 3.5.

Table 3.8: Zoning Information for WCOL Southern Parcel.

Parcel ID	Current Zoning	Required Rezoning
027-985-032	• AG (Green Belt) • AF (Agriculture and Forestry) (ALR designation) • M5 (Heavy Industrial) • M2 (General Industrial)	• M6 (Special Heavy Industrial)

(PGMap, 2019)

The eastern portion of this parcel is within the Agricultural Land Reserve (ALR), as can be seen within Figure 3.4. Prior to land use application, WCOL will undertake the proper application procedures with the designated regulatory agencies.

Development Permit Area

As previously mentioned, Riparian Protection Development Permit Areas have been identified on the WCOL Project Area. Before construction, land alteration or tree removal begins, WCOL will obtain the required permits and permissions from the designated regulatory agencies.

3.5.4 Lheidli T'enneh Land Use Plan

The Lheidli T'enneh Land Use document serves to provide support for decisions regarding land use on reserve. General reserve land objectives include:

- Enhancement and protection of culturally and environmentally sensitive areas, as well as Traditional Knowledge
- Ensure sustainable land development
- Include community input to land use decisions
- Strengthen relationships with Prince George and the RDFFG on land management issues

This Land Use Plan is prepared in alignment with the Lheidli T'enneh Land Code, which provides legal authority for planning, developing, conservation and management of Lheidli T'enneh lands.

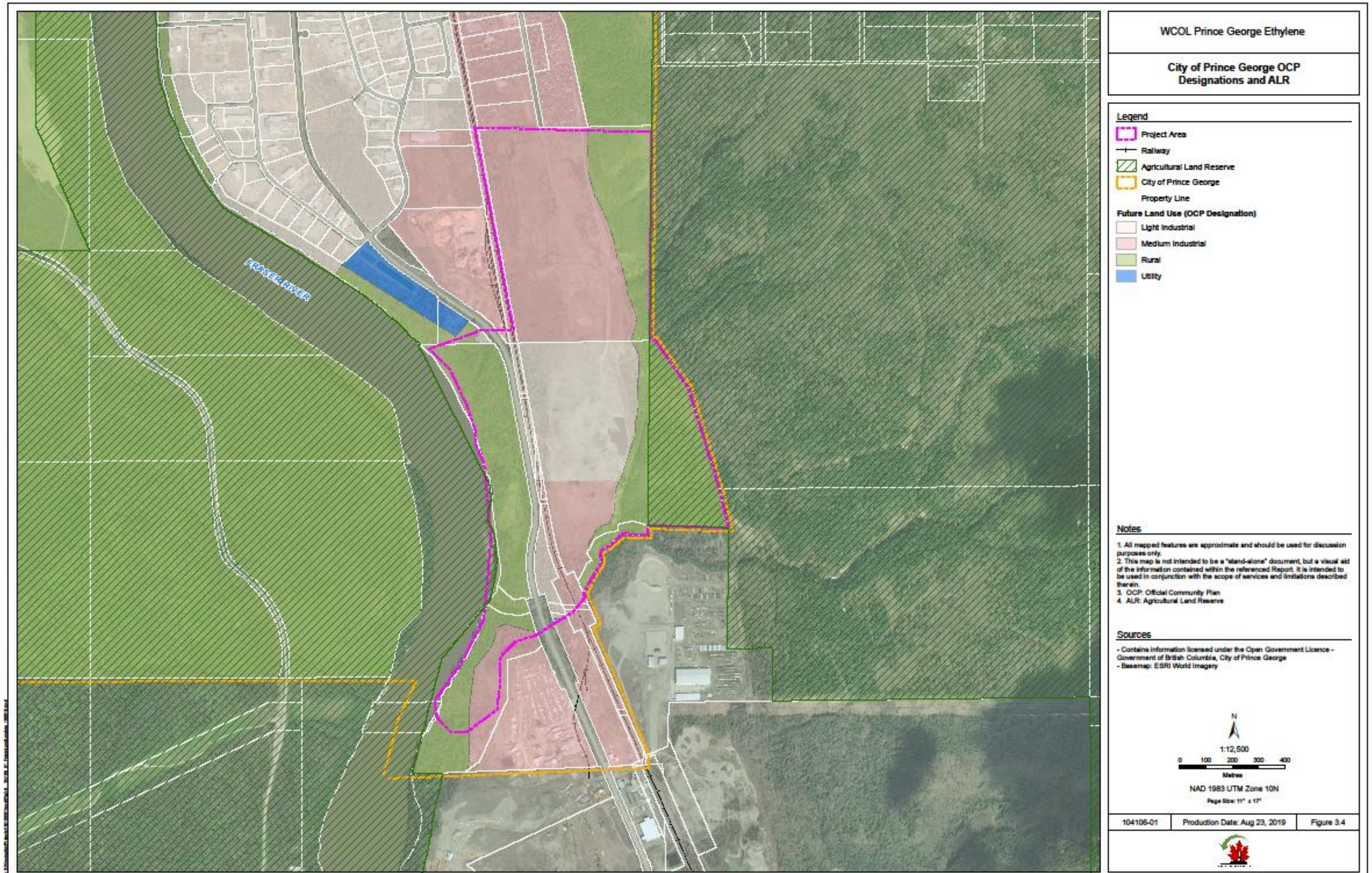

Figure 3.4: City Prince George OCP Designations of Project Area and Surrounding Area and Relevant ALR Designations.

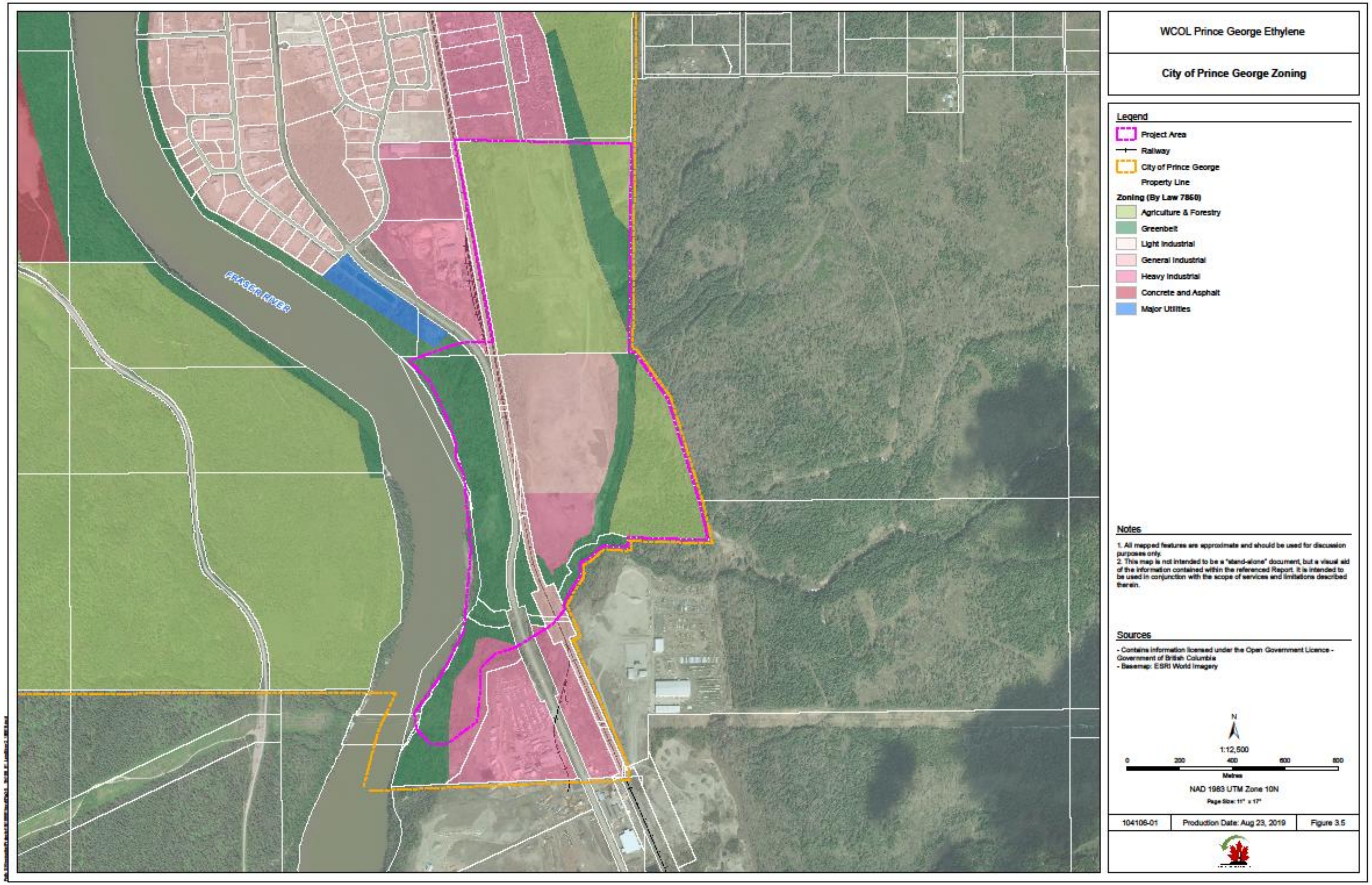

Figure 3.5: City of Prince George Zoning of Project Area and Surrounding Area.

4 Environmental Setting and Effects

The following sections provide an overview of the environmental settings in and around the Project Area. Information was gathered from publicly available sources, including scientific literature, grey literature (e.g., technical reports, government reports), and EA documentation from other projects in the area of the proposed Project. Sources of information include the following:

- Publicly available data and reports from:
  - Lheidli T'enneh First Nation (including the Lheidli T'enneh Land Use Plan)
  - Nazko First Nation
  - Statistics Canada (including the census data for City of Prince George)
  - Environment and Climate Change Canada
  - BC Ministry of Environment and Climate Change Strategy (including the BC Air Data Archive)
  - BC Ministry of Forests, Lands, Natural Resource Operations and Rural Development
  - BC Assembly of First Nations (including the Community Profiles for Lheidli T'enneh First Nation and Nazko First Nation)
  - City of Prince George (including the Official Community Plan & Heritage Register)
  - Regional District of Fraser-Fort George
  - Prince George Air Improvement Roundtable (including the Prince George Airshed database)

- Publicly available reports from other projects and activities in the region:
  - Blackwater Gold Project
  - Merrick Pipeline Project
  - Gisome Quarry and Lime Plant
  - Isle Pierre Wind Project
  - Mount George Wind Park Project
  - Pembina Condensate Pipeline Project
  - Prince George Wood Residue Fired Cogeneration Project
  - Hart Water Supply Improvements Fishtrap Island Collector Well Project

This information will be augmented with data from Project-specific studies that will be undertaken to support the environmental, economic, social, health and heritage effects assessments for the Project.

4.1 Biophysical Setting

4.1.1 Atmospheric Environment

Climate and Weather

The Project Area has experienced subarctic climate conditions as recently as the 1961 to 1990 climate normal period. Due to recent warming, the area has changed to a humid continental climate. Based on 1981 to 2010 climate normal data for the Prince George Airport (ECCC, 2019), average monthly temperatures ranged from -7.9°C in January to 15.8°C in July. Cold continental arctic air masses dominate in the winter, although air flows are restricted by the Columbia and Rocky Mountains to the east, creating milder winters than the latitude and elevation may suggest. Summer days are warm, with an average daily maximum of 22.4°C in July, but nights are often cool, with an average daily minimum less than 10°C. Located in the rain shadow of the Coast Mountains, the area tends to be dry, receiving only 595 mm of precipitation annually. Other than a somewhat drier spring, there is little precipitation difference between the seasons (Pike, Redding, Moore, Winkler, & Bladon, 2010).

Air Quality

The Project area is situated within the Prince George airshed. Located at the confluence of the Nechako and Fraser rivers, this is an area that is susceptible to poor air quality conditions. The Prince George airshed has a number of emission sources, including industrial facilities, residential heating and wood smoke, transportation corridors and road dust. Influenced by frequent light winds and temperature inversions in the winter, these air emissions tend to remain trapped in the river valley. In addition, the airshed has been subject to elevated pollutant concentrations due to wildfires in the region (PGAIR, 2019).

Air quality monitoring in the airshed consists of one core station located at the Plaza 400 in downtown Prince George, which measures particulate matter (PM_{10} and $PM_{2.5}$), sulphur dioxide, nitrogen dioxide, ozone, and total reduced sulphur. Several other stations in the area also measure 1 to 3 of the aforementioned pollutants. In 2017, 24-hour PM_{10} and $PM_{2.5}$ concentrations at Plaza 400 exceeded the BC ambient air quality objectives 3.2% and 6.5% of the time, respectively. Most of these exceedances were a result of wildfires. The remaining exceedances generally occurred during the winter and were a result of wood-burning emissions combined with stagnant meteorological conditions. There are no BC ambient air quality objectives for total reduced sulphur; however, in 2017, total reduced sulphur concentrations at Plaza 400 exceeded the pollution control objectives for the forest products industry more than 11% of the time. All other pollutants were less than relevant BC ambient air quality objectives (MOECCS, 2019).

Acoustic Environment

There is no historical information available on noise levels in or around the Project Area. However, the Project is located on previously disturbed land within an existing industrial area. Nearby industrial operations include the CN Rail yard and associated rail tracks, a wood pellet production facility, a lumber yard and several freight shipping and trucking companies. Noise levels in the area are expected to be relatively high. A noise monitoring program will be conducted to collect baseline noise levels in the Project Area in support of an Environmental Assessment Application.

4.1.2 Freshwater Environment

Groundwater

Two groundwater wells (Well Tag Numbers 56895 and 74538) are present in the Project area (iMap BC, 2019), as depicted within Figure 4.1. As described in Section 3.3, it is not yet known if these wells will be used as groundwater supply for Project process water requirements. Further design will be developed prior to the application to determine the raw water source(s).

Fish and Fish Habitat

The Project area is bounded by the Fraser River to the east and has 2 drainages that flow through its boundaries: an unnamed drainage and Haggith Creek. Figure 4.1 depicts the existing water use and watercourses relative to the Project Area.

Unnamed Drainage

The unnamed drainage, located at the north end of the Project Area, is a straight, low-gradient, first-order drainage that is approximately 260 m in length from its origin to its confluence with the Fraser River. The drainage is vegetated, and based on the topographic characteristics of the region, is likely a rainfall and snowmelt catchment for the surrounding area. No historical fish information is available for the drainage.

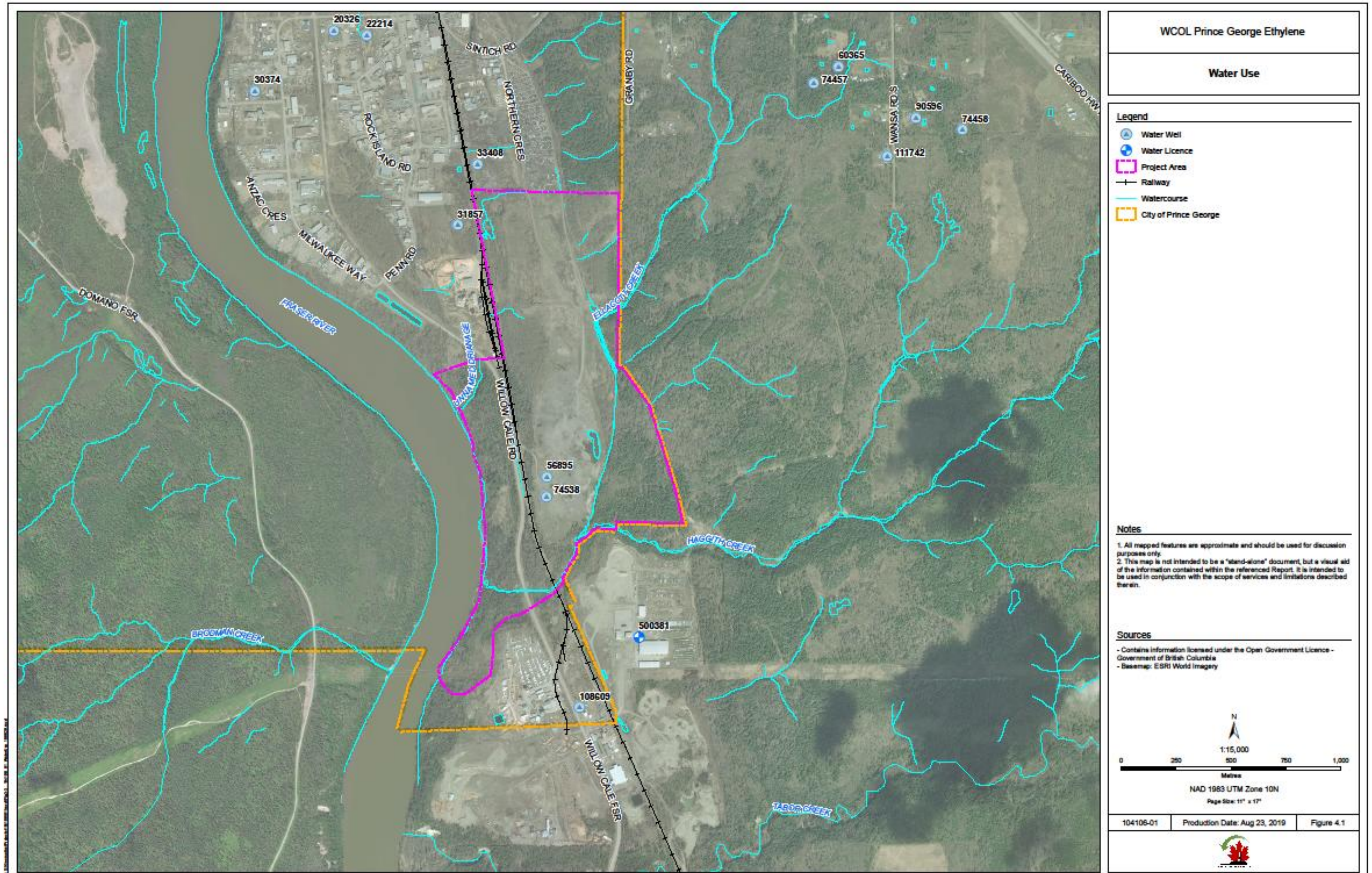

Figure 4.1: Water Use on Project Area and Surrounding Area.

Haggith Creek

Haggith Creek is a meandering, third-order drainage, approximately 14.5 km in length, and originates in the elevated plateau east of the Project Area. The riparian vegetation surrounding the creek is largely intact in the Project Area except for 2 existing watercourse crossings associated with the rail line and Willow Cale Road. Based on the documented presence of various fish species, Haggith Creek likely supports fish populations during various life stages at different times of the year. Known historic fish species occurrences are presented in Table 4.1 below.

Fraser River

The Fraser River in the vicinity of the Project Area is characterized as a productive deep run habitat with variable substrate and a straight channel pattern and ranges in width from 200 to 250 m. The river supports a variety of fish species through various life stages. Documented fish species occurrences in the Fraser River are presented in Table 4.1. The table lists those species identified in the vicinity of Prince George as identified in the BC Habitat Wizard (BC 2019a) database and does not represent all the species present in the Fraser River. It is anticipated that additional species are present in the river at this location during various life stages (e.g., rearing, migration, overwintering).

Table 4.1: Documented Fish Species Occurrences in Watercourses in or adjacent to the Project Area.

Common Name	Scientific Name	Provincial Conservation Status	Federal Conservation Status
Fraser River			
Chinook Salmon	*Oncorhynchus tshawytscha*	Yellow	Special Concern
Rainbow Trout	*Oncorhynchus mykiss*	Yellow	Not listed
Redside Shiner	*Richardsonius balteatus*	Yellow	Not listed
Peamouth Chub	*Mylocheilus caurinus*	Yellow	Not listed
Mountain Whitefish	*Prosopium williamsoni*	Yellow	Not listed
Largescale Sucker	*Catostomus macrocheilus*	Yellow	Not listed
White Sucker	*Catostomus commersonii*	Yellow	Not listed
Prickly Sculpin	*Cottus asper*	Yellow	Not listed
White Sturgeon	*Acipenser transmontanus*	Red	Endangered
Pygmy Whitefish	*Prosopium coulterii*	Yellow	Not at Risk
Northern Pikeminnow	*Ptychocheilus oregonensis*	Yellow	Not listed
Leopard Dace	*Rhinichthys falcatus*	Yellow	Not at Risk

Common Name	Scientific Name	Provincial Conservation Status	Federal Conservation Status
Haggith Creek			
Bull Trout	*Salvelinus confluentus*	Blue	Special Concern
Chinook Salmon	*Oncorhynchus tshawytscha*	Yellow	Special Concern
Northern Pikeminnow	*Ptychocheilus oregonensis*	Yellow	Not listed
Rainbow Trout	*Oncorhynchus mykiss*	Yellow	Not listed
Redside Shiner	*Richardsonius balteatus*	Yellow	Not listed

Notes:

1. Common names – BC Habitat Wizard (Government of BC, 2019)
2. Conservation status -

Source – BC Species and Ecosystem Explorer 2019

4.1.3 Terrestrial Environment

The Project Area is surrounded by the Fraser River to the west, mature mixed forest to the east, and industrial operations to the north and south. A large area where the Project facilities will be located has previously been cleared of vegetation.

The Project Area is located outside any active Wildlife Habitat Areas, Ungulate Winter Range, or Old Growth Management Areas (iMap BC, 2019). Furthermore, there is no critical habitat for federally protected terrestrial species at risk within or near the Project Area boundary (iMap BC, 2019).

Biogeoclimatic Zone and Ecoregion

The Project Area is located in the Sub-boreal Spruce (SBS) biogeoclimatic zone, between the moist hot (mh) subzone to the west and the moist cool 1 (mk) subzone to the east. In the SBS mh area, Douglas-fir (*Pseudotsuga menziesii*) and paper birch (*Betula papyrifera*) can be found with beaked hazelnut and thimbleberry making up the understorey. In contrast, in the SBS mk region, lodgepole pine and hybrid white spruce dominate the landscape, with wild sarsaparilla (*Aralia nudicaulis*), black huckleberry (*Gaylussacia baccata*), and bunchberry (*Cornus canadensis*) found in the understorey (Meidinger, Polar, & Harper, 1991).

Further, the Project Area is located in the southeastern area of the Nechako Lowland Ecosection, in the southern portion of the Fraser Basin Ecoregion, which lies within the Sub-boreal Ecoprovince. This is an area of flat to gently rolling lowland with evidence of glaciation, including eskers, drumlins and meltwater channels (Meidinger, Polar, & Harper, 1991).

Terrain and Soils

The Project Area is located directly adjacent to the Fraser River and is comprised predominantly of fluvial soils. Specifically, the soil series associated with this area is Fraser or McGregor (Dawson, 1998). Fraser soils are well or moderately well drained and are Othic Gray Luvisols, made up of silt loam or silty clay surface and subsurface soils (Dawson, 1998). McGregor soils are mainly Regosols, lacking soil development due to recent deposition, or Gleysolic soils in depressions and low-lying, poorly drained areas. They can be characterized by silt loam or sandy loam soil textures (Dawson, 1998).

Vegetation

Nearly 800 vascular plants are known to occur in the Prince George Forest District (BC E-Flora, 2018). Only 11 provincially listed at-risk species have the potential to occur in the Project Area (Table 4.2; (BC CDC, 2019)).

Table 4.2: At-risk Plant Species with Potential to Occur in the Project Area (BC CDC, 2019).

Common Name	Scientific Name	Provincial Conservation Status	Federal Conservation Status
American Sweet-flag	*Acorus americanus*	Blue	Not listed
Sprengel's Sedge	*Carex sprengelii*	Blue	Not listed
-	*Meesia longiseta*	Blue	Not listed
-	*Myrinia pulvinata*	Red	Not listed
Pygmy Waterlily	*Nymphaea tetragona*	Blue	Not listed
Davis' Locoweed	*Oxytropis campestris* var. *davisii*	Blue	Not listed
Whitebark Pine	*Pinus albicaulis*	Blue	Endangered
-	*Pohlia elongata*	Blue	Not listed
-	*Rhodobryum roseum*	Blue	Not listed
-	*Sphagnum wulfianum*	Blue	Not listed
Short-flowered Evening Primrose	*Taraxia breviflora*	Red	Not listed

Terrestrial Wildlife

The Prince George Forest District has abundant and diverse wildlife. There is potential to find over 250 bird species nesting and migrating through the area and over 50 mammal species as well as 7 amphibians and reptiles using the area.

Birds

There is a diversity of bird species in the Prince George area. Known occurrences of species at risk include the BC red-listed American white pelican (*Pelecanus erythrorhynchos*) and the federally Threatened olive-sided flycatcher (*Contopus cooperi;* (BC CDC, 2019)). With over 250 birds found in the area, only the provincial and federal at-risk avian species with the potential to occur in the Project Area are listed in Table 4.3.

Table 4.3: At-risk Bird Species with Potential to Occur in the Project Area (BC CDC, 2019).

Common Name	Scientific Name	Provincial Conservation Status	Federal Conservation Status
American Bittern	*Botaurus lentiginosus*	Blue	Not listed
American White Pelican	*Pelecanus erythrorhynchos*	Red	Not listed
Barn Swallow	*Hirundo rustica*	Blue	Threatened
Black Swift	*Cypseloides niger*	Blue	Not listed
Bobolink	*Dolichonyx oryzivorus*	Blue	Threatened
Broad-winged Hawk	*Buteo platypterus*	Blue	Not listed
Common Nighthawk	*Chordeiles minor*	Yellow	Threatened
Eared Grebe	*Podiceps nigricollis*	Blue	Not listed
Great Blue Heron, *herodias* subspecies	*Ardea herodias herodias*	Blue	Not listed
Long-billed Curlew	*Numenius americanus*	Blue	Special Concern
Northern Goshawk, *atricapillus* subspecies	*Accipiter gentilis atricapillus*	Blue	Not listed
Olive-sided Flycatcher	*Contopus cooperi*	Blue	Threatened
Rusty Blackbird	*Euphagus carolinus*	Blue	Special Concern

Common Name	Scientific Name	Provincial Conservation Status	Federal Conservation Status
Short-eared Owl	*Asio flammeus*	Blue	Special Concern
Sharp-tailed Grouse, *columbianus* subspecies	*Tympanuchus phasianellus columbianus*	Blue	Not listed
Winter Wren	*Troglodytes hiemalis*	Blue	Not listed

Mammal, Amphibians and Reptiles

Hunting is a popular recreational activity in the Prince George area due to the diversity of ungulates. In the Project Area, there is potential to come across mule deer (*Odocoileus hemionus*), white-tailed deer (*Odocoileus virginianus*), moose (*Alces americanus*) and elk (*Cervus elaphus*), as well as the provincially red-listed and federally Threatened southern mountain caribou (*Rangifer tarandus*). Table 4.4 lists the ungulates as well as the other mammals and their conservation status with the potential to occur in the Project Area (BC CDC, 2019).

Table 4.4: Mammal Species with The Potential To Occur In The Project Area (BC CDC, 2019).

Common Name	Scientific Name	Provincial Conservation Status	Federal Conservation Status
Mule Deer	*Odocoileus hemionus*	Yellow	Not listed
White-tailed Deer	*Odocoileus virginianus*	Yellow	Not listed
Moose	*Alces americanus*	Yellow	Not listed
Caribou	*Rangifer tarandus*	Red	Threatened
Elk	*Cervus elaphus*	Yellow	Not listed
Cougar	*Puma concolor*	Yellow	Not listed
Lynx	*Lynx canadensis*	Yellow	Not listed
Striped Skunk	*Mephitis mephitis*	Yellow	Not listed
American Marten	*Martes americana*	Yellow	Not listed
Fisher	*Pekania pennanti*	Blue	Not listed
Least Weasel	*Mustela nivalis*	Yellow	Not listed
Short-tailed Weasel	*Mustela erminea*	Yellow	Not listed
Long-tailed Weasel	*Mustela frenata*	Yellow	Not listed
American Mink	*Neovison vison*	Yellow	Not listed
Northern River Otter	*Lontra canadensis*	Yellow	Not listed

Common Name	Scientific Name	Provincial Conservation Status	Federal Conservation Status
Wolverine	*Gulo gulo*	Blue	Special Concern
Black Bear	*Ursus americanus*	Yellow	Not listed
Grizzly Bear	*Ursus arctos*	Blue	Special Concern
Coyote	*Canis latrans*	Yellow	Not listed
Grey Wolf	*Canis lupus*	Yellow	Not listed
Red Fox	*Vulpes vulpes*	Yellow	Not listed
Common Raccoon	*Procyon lotor*	Yellow	Not listed
Meadow Jumping Mouse	*Zapus hudsonius*	Yellow	Not listed
Western Jumping Mouse	*Zapus princeps*	Yellow	Not listed
Bushy-tailed Woodrat	*Neotoma cinerea*	Yellow	Not listed
House Mouse	*Mus musculus*	Yellow	Not listed
Deer Mouse	*Peromyscus maniculatus*	Yellow	Not listed
Southern Red-backed Vole	*Myodes gapperi*	Yellow	Not listed
Western Heather Vole	*Phenacomys intermedius*	Yellow	Not listed
Meadow Vole	*Microtus pennsylvanicus*	Yellow	Not listed
Long-tailed Vole	*Microtus longicaudus*	Yellow	Not listed
Northern Bog Lemming	*Synaptomys borealis*	Yellow	Not listed
Muskrat	*Ondatra zibethicus*	Yellow	Not listed
Yellow Pine Chipmunk	*Neotamias amoenus*	Yellow	Not listed
Masked Shrew	*Sorex cinereus*	Yellow	Not listed
Dusky Shrew	*Sorex obscurus*	Yellow	Not listed
Western Water Shrew	*Sorex navigator*	Yellow	Not listed
Woodchuck	*Marmota monax*	Yellow	Not listed
Hoary Marmot	*Marmota caligata*	Yellow	Not listed
Yellow-bellied Marmot	*Marmota flaviventris*	Yellow	Not listed
Columbian Ground Squirrel	*Urocitellus columbianus*	Yellow	Not listed
Red Squirrel	*Tamiasciurus hudsonicus*	Yellow	Not listed
Northern Flying Squirrel	*Glaucomys sabrinus*	Yellow	Not listed
Porcupine	*Erethizon dorsatum*	Yellow	Not listed
Beaver	*Castor canadensis*	Yellow	Not listed
Mountain Beaver	*Aplodontia rufa*	Yellow	Special Concern
Snowshoe Hare	*Lepus americanus*	Yellow	Not listed
Long-eared Bat	*Myotis evotis*	Yellow	Not listed
Little Brown Bat	*Myotis lucifugus*	Yellow	Endangered
Silver-haired Bat	*Lasionycteris noctivagans*	Yellow	Not listed
Big Brown Bat	*Eptesicus fuscus*	Yellow	Not listed

There are 7 species of herptiles (amphibian and reptiles) that could potentially occur in the Project Area, including western toad, which is listed federally as being of Special Concern. Table 4.5 lists the herptiles potentially found in the Project Area (BC CDC, 2019).

Table 4.5: Amphibian and Reptile Species with the Potential to Occur in The Project Area (BC CDC, 2019).

Common Name	Scientific Name	Provincial Conservation Status	Federal Conservation Status
Western Toad	*Anaxyrus boreas*	Yellow	Special Concern
Columbian Spotted Frog	*Rana luteiventris*	Yellow	Not listed
Pacific Tree (Chorus) Frog	*Pseudacris regilla*	Yellow	Not listed
Wood Frog	*Lithobates sylvaticus*	Yellow	Not listed
Western Long-toed Salamander	*Ambystoma macrodactylum*	Yellow	Not listed
Common Garter Snake	*Thamnophis sirtalis*	Yellow	Not listed
Western Terrestrial Garter Snake	*Thamnophis elegans*	Yellow	Not listed

4.2 Social, Economic, Health and Heritage Setting

4.2.1 Social Setting

The City of Prince George is the largest city in northern BC, with a population of 74,003 at the time of the 2016 census. As of 2016, the City's population had grown by 2.8% in 5 years (since the 2011 census; (Statistics Canada, 2017)). With a median age of 38.4, Prince George has a relatively young population, compared to the provincial median age of 43.0. Within the population, approximately 15.1% self-identify as Aboriginal and 52.6% are female (Statistics Canada, 2017).

Prince George's profile in the region is heightened by its 2 post-secondary educational facilities, namely CNC and UNBC, which together have over 8,000 students enrolled (UNBC, 2019). The City has several health care facilities, including the University Hospital of Northern British Columbia, which is the largest healthcare facility in northern BC (UNBC, 2019).

The Regional District of Fraser-Fort George (RDFFG) is located in the central interior region of BC and comprises 4 municipalities and 7 electoral areas (RDFFG, n.d.). It was incorporated as regional district on March 8, 1967, to provide its rural residents with joint and shared services and coordinated administrative and government services at a time when the region was experiencing rapid growth due to the booming forestry and resource industries (RDFFG, n.d.). Currently RDFFG is providing more than 90 local government services to a population of approximately 94,500 (2016 census data), including emergency response, waste management, fire protection and land use planning services (Statistics Canada, 2017).

Indigenous communities (First Nation reserves) and the Traditional Territories of the Lheidli T'enneh First Nation and Nazko First Nation are shown on Figure 4.2.

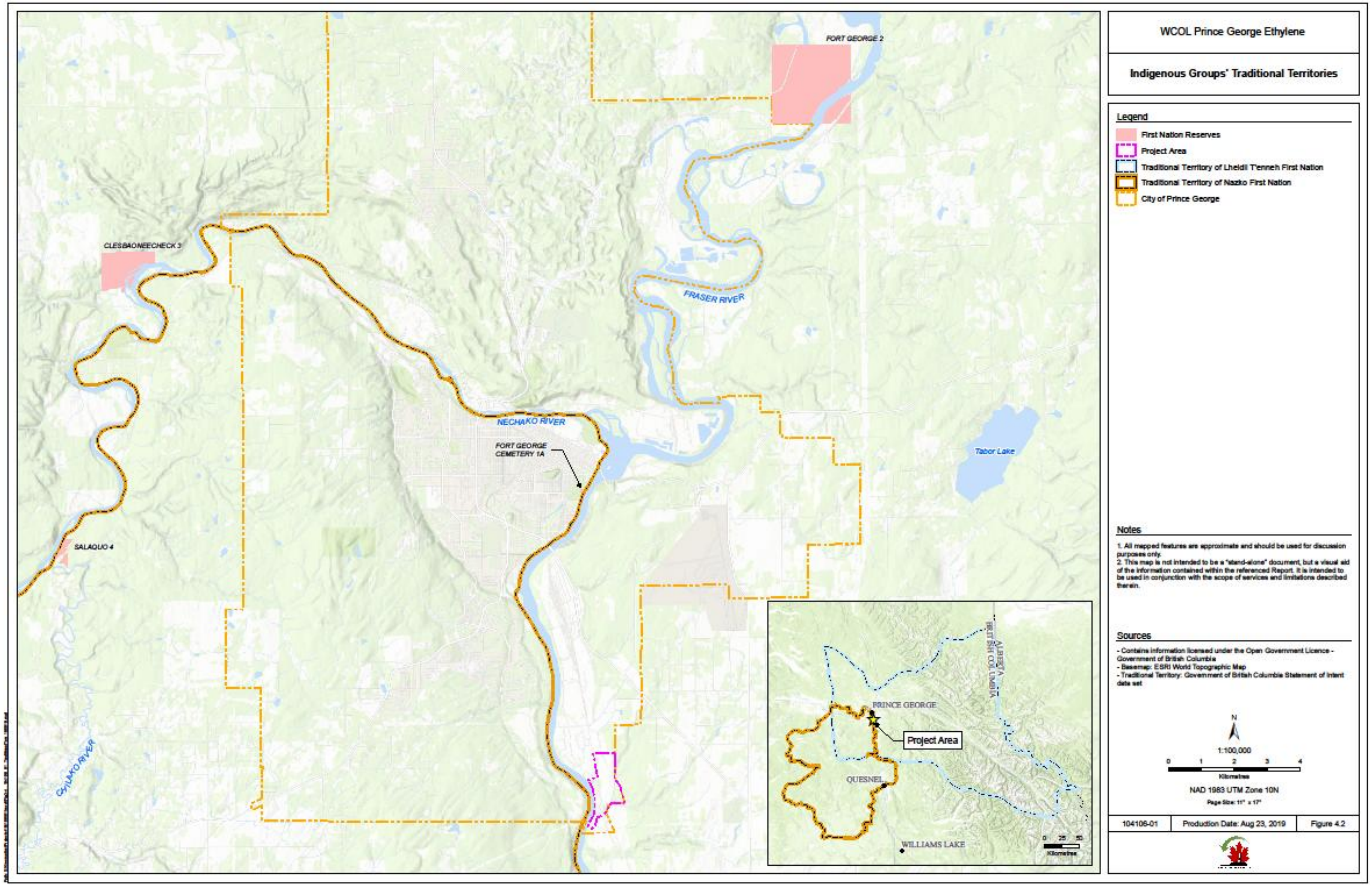

Figure 4.2: Repeat of Indigenous Groups.

The Lheidli T'enneh First Nation is of the Dakelh people. Lheidli T'enneh means "the people from confluence of 2 rivers" (BCAFN, 2019). As of July 2019, the Lheidli T'enneh First Nation had a registered population of 454 of which 49.8% were female. Within the registered population, 21.6% live on a Lheidli T'enneh First Nation Reserve (INAC, 2019).

The Nazko First Nation is also of the Dakelh people with a registered population of 405 as of July 2019, of which 48.9% were female. Within the registered population, 28.1% live on a Nazko First Nation Reserve (INAC, Registered Population: Nazko First Nation, 2019).

4.2.2 Land and Water Use

Current use of lands and resources for traditional purposes as well as non-traditional land and water use in the vicinity of the Project Area are described in this section.

Information on Traditional Use presented in this section has been obtained from publicly available sources.

Lheidli T'enneh First Nation Traditional Land Use

The Lheidli T'enneh First Nation lived in seasonal camps near the Nechako and Fraser Rivers and throughout their Traditional Territory prior to first contact and up to the early 1900s. The Traditional Territory was used seasonally for hunting, fishing, trapping and resource gathering, including fishing for salmon and other fish in the spring and summer and hunting in the mountains in the fall. The locations of the seasonal camps or resource harvesting activities were dependent on ecological and seasonal shifts such as species migratory movements and species abundance (e.g., salmon runs), and changes in water levels (Lheidli T'enneh Lands Authority, 2017).

Lheidli T'enneh Cemetery IR #1A (Ts'unk'ut) is in the City of Prince George and is located approximately 8 km north of the Project Area. Members of the Lheidli T'enneh First Nation continue to use the cemetery as a burial ground for their people (Lheidli T'enneh Lands Authority, 2017).

Nazko First Nation Traditional Land Use

The Traditional Territory of the Nazko First Nation extends from Quesnel to Prince George and was used for hunting, fishing, trapping and resource gathering (BC Treaty Commission, 2019). Traditional Uses included fishing in various lakes, cambium harvesting in the pine forests, and utilizing footpaths to trade and travel (Nazko First Nation, n.d.). Nazko First Nation members continue to actively fish, hunt and trap in their Traditional Territory for such species as moose and kokanee (ERM 2015).

Non-traditional Land and Water Use

The Project Area is situated in a developed industrial park within the Prince George BCR Industrial Area. Large portions of the Project Area have been previously cleared of vegetation from former land uses. The northern section of the Project Area was previously used as a log storage yard and later as a gravel pit.

No timber harvesting rights (e.g., Timber Licence, Licence to Cut, Special Use Permit) are actively held in or adjacent to the Project Area (iMap BC, 2019).

There are no federal or provincial designated parks or protected areas in or adjacent to the Project Area. The nearest provincial parks are Fort George Canyon Park, located approximately 14 km to the south, and West Lake Park, located approximately 12 km southwest of the Project Area (iMap BC, 2019).

An area directly adjacent to the northwestern boundary of the Project Area on the west side of Willow Cale Road is designated as an Open Space based on City of Prince George Green Belt classification (City of Prince George, 2011). Open Spaces are considered recreational areas in the City of Prince George OCP guidelines. Refer to Section 3.5 for additional information on the City of Prince George OCP.

The nearest City-designated recreational trail is located approximately 1 km north of the Project Area. Based on the City of Prince George's Active Transportation Plan, shared bike lanes exist on many of the roads surrounding the Project Area, including Sinnich Road and Penn Road. None of these roads extend into the Project Area.

The Fraser River supports a variety of fish species that can be harvested for commercial or recreational purposes, including salmonids. The Project Area partially overlaps with one Guide Outfitter Licence area (No. 700617; (iMap BC, 2019)). The river is also navigable by passenger and fishing vessels as well as recreational crafts such as kayaks or canoes. There are no boat launch locations adjacent to or near the Project Area.

4.2.3 Economic Setting

Historically, the economy in and around Prince George was based on fur trading, agriculture, and commercial trading. The city emerged as an important transportation hub with the arrival of the Grand Trunk Pacific Railway (now CN Rail) in 1914 (City of Prince George, 2017). The relative importance of these resource industries has changed over the years, but Prince George has established itself as one of the more well-diversified communities in northern BC and continues to serve as an important transportation hub through its highways and railways connecting regional businesses, resources (e.g., minerals and mines, forest products) and agricultural products to national and international markets (City of Prince George, 2017), (City of Prince George, 2017).

A considerable percentage of the labour force population works in service- and transportation-related employment sectors, with 24.7% of total labour force population aged 15 years and over in sales and services occupations and 18.5% in trades, transport, and equipment operators and related occupations in 2016 (Statistics Canada, 2017). Approximately 5.2% and 3.0% of the labour force population work in the natural and applied sciences and the natural resources, agriculture and related production sectors, respectively. The unemployment rate in 2016 was 9.3%, compared to 6.7% in BC overall; however, the prevalence of low-income earners in Prince George was 13.3%, lower than the provincial average of 15.5%. In 2015, the median total income of households in Prince George was $75,690, compared to the Canadian median of 70,336 (Statistics Canada, 2017).

Economic activities of the Lheidli T'enneh First Nation and the Nazko First Nation include resource-based activities such as timber harvesting and natural resource management. The Lheidli T'enneh First Nation has several economic development initiatives that include a timber harvesting company in joint venture with Roga Contracting Ltd. and fisheries management with Fisheries and Oceans Canada (Lheidli T'enneh, n.d.). The Nazko Economic Development Corporation works for the Nazko First Nation through the Chief and Council and oversees the operation of Nazko Logging Limited Partnership, Besikoh Fuel LP and Blackwater Camp Services (NEDC, 2019).

4.2.4 Health Setting

The Project Area is located in the Prince George Local Health Area (LHA), which is 1 of the 4 Northern Interior Health Service Delivery Areas, with approximately 76.4% of the Prince George LHA population living in the City of Prince George (Northern Health, 2016).

Environmental Quality

Current conditions related to air quality, noise and surface water quality are described in Sections 4.1.1 and 4.1.2.

Although the Project Area is currently untenanted, there are several land-based air emission and noise emission sources in proximity with commercial and industrial manufacturing, storage and distribution facilities to the north and south. Based on the past and current use of the lands in and around the Project Area, there is potential for the soil to contain contaminants of concern. Soil quality will be investigated as part of the Project's baseline study program.

The potential for contaminants of concern in surface water, soils and sediments will be investigated as part of a Human Health Risk Assessment undertaken for the Project. This risk assessment will characterize exposure potential by human receptors to all chemical and physical stressors based on measured (baseline) and predicted future concentrations or levels for the nearby population.

Social Determinants of Health

Social determinants of health include income, education, adequate housing, food security, early childhood development and many other factors. The 2012 socio-economic indices available for the Prince George LHA indicate that health outcomes (e.g., health problems, human economic hardship) in the region are generally lower than the BC average (Government of BC, 2013). The LHA also has a higher percentage of the population on income assistance than the provincial average. While the area has seen a significant reduction in serious violent and property crimes since 2006, the LHA's rate is still higher than the provincial average. For example, the total serious crime rate for the LHA was 14.2 per 1,000 in population in 2012 compared to the provincial average rate of 11.1 (Government of BC, 2013).

In 2015, the City had a lower average total income of $60,000 for its lone-parent economic families compared to the BC average of $63,004. However, low-income seniors are less prevalent in Prince George compared to the provincial average (Statistics Canada, 2016).

At the time of the 2016 survey, fewer adults in Prince George had completed post-secondary education than the provincial average (Statistics Canada, 2016).

Housing indicators, such as dwellings in need of major repairs and housing affordability, are a gauge of living conditions and community health and well-being. Dwellings in need of major repairs totalled approximately 7.9% in Prince George, contrasting with a 6.7% average across BC (Statistics Canada, 2016).

Child and youth health is critical to the overall health and well-being of a community. The vulnerability of young children in terms of social, physical, emotional, language and communication development was generally higher in the Prince George LHA compared to BC overall. Similarly, higher than provincial average percentage of children and youth were perceived to be at risk (Government of BC, 2013).

4.2.5 Heritage Setting

Heritage resources are protected under provincial and municipal legislation. The City of Prince George has a heritage register that lists 13 heritage sites within its jurisdiction. The register includes a Statement of Significance for each heritage site outlining its historical significance and heritage value. None of the registered heritage sites are located within or adjacent to the Project Area, with the nearest located approximately 7 km north of the Project Area (City of Prince George, 2017). In addition, the nearest archaeological potential area is more than 2 km north of the Project Area (City of Prince George, 2011).

The provincial archaeological database (Remote Access to Archaeological Data; RAAD) indicates no registered archaeological sites in the Project Area, with the nearest being approximately 500 m away on the west side of the Fraser River (site ID FkRq-1). No archaeological studies (e.g., Archaeological Overview Assessment) have been registered for the Project Area (RAAD, 2019).

4.3 Potential Environmental Effects

To support BC EAO in determining the need for and potential scope of a provincial EA, a summary of the potential environmental, economic, social, heritage and health effects of the Project has been prepared based on general knowledge of the Project and the existing natural and human environment.

The construction and operation of the Project will alter the physical environment at and around the Project Area. Construction activities are anticipated to disturb vegetation, soils and existing ecological processes. Although subject to the final layout of the Project footprint, there is also potential for construction and operation activities to affect nearby surface watercourses. Atmospheric emissions and noise generated by the Project activities will alter the visual and noise conditions at or some distance from the Project Area. Accidents or malfunctions could alter the quality of air, soil and surface water. These changes in the physical environment may result in potential environmental, social, economic, heritage or health effects. Potential adverse effects (prior to the application of mitigation measures) are summarized in Table 4.6 along with the Project-related activities that may potentially cause these effects.

Because the Project is located approximately 180 km from the Alberta border, approximately 700 km from the Yukon border and approximately 500 km from the Canada-USA border (Alaska), no adverse environmental effects outside the province of BC are anticipated. Neither the legislation of other provinces nor inter-provincial/cross-border legislation is triggered by the Project. The scope of anticipated environmental effects is confined to the province of BC and the Project areas identified in this document.

Residual adverse effects associated with the Project have the potential to interact with the residual adverse effects from other past, present and reasonably foreseeable projects and activities leading to cumulative effects. As such, and in compliance with provincial guidelines and guided by industry standard guidance such as those from the Canadian Environmental Assessment Agency (CEAA, 2015) and (CEAA, 2017), a cumulative effects assessment will be conducted for the Project and presented in the Application. Types of developments and activities with the potential to interact cumulatively with the Project include:

- Past and current developments and activities at and near the Project Area
- Industrial, commercial and urban land development in Prince George and the RDFFG
- Commercial and recreational use of the Project Area and its surrounding environment, including the Fraser River

Given the current stage of development, knowledge of the Project's potential for generating residual effects is preliminary and therefore a fulsome understanding of cumulative effects is not possible. However, based on current knowledge of the Project's interactions and such residual effects of other projects and activities in the area, the following cumulative interactions will, at a minimum, be investigated during scoping for the Project's cumulative effects assessment:

1. Air emissions (type and quantity) as they relate to other industrial emissions in the regional airshed.
2. Water extraction as it relates to the quantity of water available after consideration for other uses such as domestic and industrial. Metrics will likely include consideration for fish and fish habitat as well as human consumption.
3. Noise as it relates to published thresholds for industrial areas (i.e., OGC policy), taking into consideration the existing conditions in the Project Area.
4. Construction period effects such as the influx of workers and transportation needs that interact with the demands on infrastructure and public services as a result of other projects and activities.

Table 4.6: Potential Project-related Effects.

Component	Key Project Activities	Potential Adverse Project Effect
Environment		
Fish and Fish Habitat	• **Construction**: potential removal and displacement of aquatic vegetation, elevated surface erosion and runoff, disturbance of substrates and riparian vegetation and other habitat features during clearing and construction of access roads, construction of intake and outfall infrastructure and construction of stream crossings. • **Operations:** temporary disruption of habitat during maintenance and clearing activities associated with intake operations (e.g., backflushing, intake maintenance, clearing of rafted debris); deleterious releases into receiving waterbodies as a result of spills and upset conditions during normal operations. • **Decommissioning**: potential removal and displacement of aquatic vegetation, substrates, riparian vegetation and other habitat features during the removal and decommissioning of access roads, the intake and outfall infrastructure and any stream crossings.	• Loss of fish habitat during construction of the water intake and outfall structures. • Loss or degradation of aquatic habitat due to changes in water quality or nuisance effects resulting from noise generation by the Project. • Disturbance of fish life-stage activities (e.g. rearing, migration) during maintenance activities. • Fish entrainment related to operation of the intake structure on the Fraser River. • Increased surface erosion and runoff as a result of site clearing for construction and operations activities.

Component	Key Project Activities	Potential Adverse Project Effect
Groundwater	• **Construction**: Potential introduction of contaminants into shallow aquifers as a result of surface spills during establishment of wells. • **Operations:** Potential introduction of contaminants into shallow aquifers as a result of surface spills during operations on the site of wells. Potential impacts on surface water discharge levels as a result of groundwater extraction flow rates. Potential impact on adjacent licenced users ability to draw water based on hydraulic connectivity. • **Decommissioning**: Potential introduction of contaminants into shallow aquifers as a result of surface spills during decommissioning activities.	• Shallow aquifers can to be unconfined and thus may have limited protection from surface activities such as potential contaminant discharge (i.e., spills) that may adversely affect water quality. • Shallow aquifers can be subject to seasonal discharge/recharge effects and the addition of new wells in the area may have a detrimental effect on existing approved licence holders in the area. • Based on the hydrologic connectivity of the aquifer, groundwater extraction can influence levels in nearby surface watercourses based on withdrawal rates.
Terrestrial Vegetation (including riparian)	• **Construction**: Potential clearing and grubbing of areas not already cleared for industrial activity; potential grading when required for Project infrastructure; construction of buildings, laydown areas, and waste disposal and recycling facilities in accordance with applicable legislation; potential rehabilitation and stabilization of areas not required for the operation phase. • **Operation**: Planned and unplanned maintenance. • **Decommissioning**: Decommissioning Project components that contain hazardous waste and other chemicals.	• Permanent changes in available habitat may occur. • Habitat may be lost from construction and decommissioning of infrastructure. • Mortality associated with Project construction. • Proliferation of non-native and invasive species may reduce biodiversity and reduce habitat quality. • Changes in air, soil, or water quality may damage vegetation and degrade or reduce available habitat.

Component	Key Project Activities	Potential Adverse Project Effect
Terrestrial Wildlife	• **Construction**: Potential clearing and grubbing of areas not already cleared for industrial activity; potential grading when required for Project infrastructure; construction of buildings, laydown areas and waste disposal and recycling facilities in accordance with applicable legislation; potential rehabilitation and stabilization of areas not required for the operation phase. • **Operation**: Planned and unplanned maintenance. • **Decommissioning**: Decommissioning project components that contain hazardous waste and other chemicals.	• Loss or degradation of terrestrial habitat may occur due to changes in vegetation soil, water quality and air quality, or to nuisance effects resulting from noise generation by the Project. • Changes in movement patterns of wildlife may occur due to displacement by Project activities. • Injury or mortality to wildlife, may result from land clearing activities and from traffic associated Project infrastructure. • Indirect loss of habitat and potential habitat may occur due to sensory disturbance and change in behaviour associated with construction and operation activities, including noise, light, air emissions and human presence. • Barriers to movement may be created.

Component	Key Project Activities	Potential Adverse Project Effect
Economic		
Local and Regional Economy	• **Construction**: All construction activities. • **Operation**: All operation activities. • **Decommissioning**: All decommissioning activities.	• Direct and indirect Project demands for goods and services may influence the availability of goods and services at a local level. • Potential disruption of local businesses (e.g., increased road traffic near the Project Area).
Labour Market	• **Construction**: All construction activities. • **Operation**: All operation activities. • **Decommissioning**: All decommissioning activities.	• Project employment may result in changes to the local regional labour market. • Project employment may result in changes in local annual wage and salary levels as well as labour income.
Social		
Infrastructure and Services	• **Construction**: All construction activities. • **Operation**: All operation activities. • **Decommissioning**: All decommissioning activities.	• Project employment may result in temporary and permanent in-migration of workers, which could increase the demand for supporting social and health infrastructure, services and housing. • Increased road traffic may result in degradation of major roads in the area.

Component	Key Project Activities	Potential Adverse Project Effect
Current Use of Lands and Resources for Traditional Purposes	• **Construction**: Potential clearing and grubbing of areas not already cleared for industrial activity; potential grading when required for project infrastructure; construction of administrative buildings, laydown areas and waste disposal and recycling facilities in accordance with applicable legislation; potential rehabilitation and stabilization of areas not required for the operation phase. • **Operation**: All operation activities. • **Decommissioning:** Decommissioning project components that contain hazardous waste and other chemicals.	• Access to lands, waters and resources currently used for traditional purposes may be affected or disrupted. • The quality and quantity of the resources currently used for traditional purposes may be affected or reduced (e.g., from site clearing, increased road traffic). • The quality of the current use experience may be affected due to nuisance effects (e.g., noise, light) or changes in air quality. • The ability to transfer Indigenous knowledge and fulfill the cultural purpose of current use activities may be affected.
Land, Water, and Resource Use (including recreational and commercial uses)	• **Construction**: Potential clearing and grubbing of areas not already cleared for industrial activity; potential grading when required for Project infrastructure; construction of buildings, laydown areas, and waste disposal and recycling facilities in accordance with applicable legislation; potential rehabilitation and stabilization of areas not required for the operation phase. • **Operation:** All operation activities. • **Decommissioning**: Decommissioning project components that contain hazardous waste and other chemicals.	• Access to land, water and resources use at or adjacent to the Project Area may be affected. • Use of land, water and resources at or adjacent to the Project Area may be affected by potential changes in air quality, increases in road traffic, changes in the distribution, abundance or quality of resources (e.g., plants or other animals) and nuisance effects (e.g., noise, light).

Component	Key Project Activities	Potential Adverse Project Effect
Community Health and Well-being	• **Construction**: All construction activities. • **Operation**: All operation activities. • **Decommissioning**: All decommissioning activities.	• The influx of workers to the local communities surrounding the Project Area may result in adverse effects on vulnerable sub-populations, such as children and youth, seniors, and low-income families. Adverse effects may include: ▫Increased risk of communicable and non-communicable diseases ▫Increased drug and alcohol use ▫Increased crime ▫Adverse effects on mental health and wellness ▫Change in accidents and injuries ▫Increased pressure on health services structure and capacity ▫Adverse effects on community quality of life
Visual Quality	• **Construction**: All construction activities. • **Operation**: All operation activities. • **Decommissioning**: All decommissioning activities.	Physical changes to the site may affect the visual quality at the proposed site and surrounding area; however, the Project Area is already heavily industrialized.

Component	Key Project Activities	Potential Adverse Project Effect
Heritage		
Archaeological and Heritage Resources	• **Construction**: Potential clearing and grubbing of areas not already cleared for industrial activity; potential grading when required for project infrastructure; construction of buildings, laydown areas and waste disposal and recycling facilities in accordance with applicable legislation; potential rehabilitation and stabilization of areas not required for the operation phase. • **Operation**: Planned and unplanned maintenance. • **Decommissioning**: All decommissioning activities.	• Loss of or damage to archaeological and heritage resources (including contextual information) may occur due to ground disturbance or clearing associated with the Project.
Health		
Human Health	• **Construction**: All construction activities. • **Operation**: All operation activities. • **Decommissioning**: All decommissioning activities.	• Changes in air, water or soil quality may result in changes in health risks to individuals exposed to those media. • Changes in ambient noise conditions may result in direct and indirect changes to human health. • Changes in air, water or soil quality that alter the quality of country foods (both plants and animals) may affect the health of individuals who consume them.

4.4 Measures to Prevent or Reduce Potential Effects

Based on preliminary identification of potential Project-related adverse effects summarized above, initial measures to prevent or reduce these effects to an acceptable level have been incorporated or are currently being considered in the design of the Project. These include siting the facilities away from residential areas in an existing disturbed industrial area that has been partially cleared from previous operations. Additional design considerations include: sourcing the facilities' energy needs from the BC Hydro grid; using a low-carbon, clean-burning mixture of methane and hydrogen as a main fuel source for fired equipment; recovering heat from the Pyrolysis Furnaces to supply other Project processes; and investigating the supply of low-grade waste heat to a greenhouse operation. Additional design considerations are to be considered as much as possible. As the design of the Project continues to progress, additional measures to mitigate potential effects will be incorporated based on compliance with:

- Applicable federal and provincial legislations and regulations (e.g., *Fisheries Act*, *Environmental Management Act, Wildlife Act*).
- WCOL will follow applicable Canadian engineering codes and standards from organizations such as the Canadian Standards Association and Technical Safety BC. WCOL will reference and utilize codes, standards and recommended practices as appropriate from industry recognized organizations such as the National Fire Protection Association, American Society of Mechanical Engineers, American Petroleum Institute and the International Society of Automation.
- Best management practices (e.g., BC Noise Control Best Practices Guideline (BC OGC, 2009); Guidelines for Raptor Conservation during Urban and Rural Land Development in BC (Government of BC, 2013)).
- Future project management plans to be developed for the Project (e.g., Emergency Response Plan, Security Management Plan, Environmental Management Plans, Workforce Management Strategy).
- Project-specific measures identified during the EA process, the engagement and consultation processes, and permitting.

To confirm the effects of the Project and the effectiveness of the applied mitigation, WCOL will develop and implement monitoring programs during the construction and operation phases of the Project. Monitoring programs may include specifics for:

- Air quality
- Noise
- Freshwater fish and other aquatic life
- Terrestrial wildlife
- Discharges to air, water and land
- Cultural and heritage sites

The above list is not exhaustive and will be refined throughout the EA process.

5 Engagement and Consultation

WCOL is a strong advocate for the importance of engagement with local community when executing a major new project; WCOL Project team members have been meeting with local First Nations, different levels of government, various community institutions and members of the community throughout 2019. This section summarizes WCOL's approach to community engagement and consultation related to the Ethylene Project, and in this section, we summarize past and future engagement and consultation activities with Indigenous groups, regulators, government, the public and other potential stakeholders.

5.1 Indigenous Engagement

WCOL initiated early discussions with the Lheidli T'enneh First Nation on February 4 and 5, 2019; these discussions reflect WCOL's early commitment to this relationship. Since that introductory meeting, WCOL has continued to work with Lheidli T'enneh to develop a relationship, familiarize Lheidli T'enneh with the project, understand the Lheidli T'enneh First Nation's concerns and ambitions and socialize the project within the Lheidli T'enneh community. Following is a summary of key meetings and milestones to date:

Table 5.1: Engagements with Lheidli T'enneh.

Engagements with Lheidli T'enneh	
February 4–5, 2019	Meeting with Rena Zatorsky to introduce WCOL
March 28, 2019	Prince George Contractors Workshop #1 attended by Rena Zatorsky
April 10, 2019	Clayton Pountney elected Chief of Lheidli T'enneh First Nation for 2-year term
April 30, 2019	Introductory meeting with Chief Pountney and Council
June 19, 2019	Meeting with Chief Pountney and Rena Zatorsky
June 25, 2019	Non-disclosure Agreement signed between WCOL and Lheidli T'enneh
July 9, 2019	Meeting of WCOL and Mayor Hall with Lheidli T'enneh Chief and Council
July 10, 2019	Meeting with WCOL and Lheidli T'enneh Economic Development Team (Rena Zatorsky, Helen Buzas, Dolleen Logan and Scott Smith (the latter from Gowlings law firm)) to discuss Project scope and regulatory path forward
July 13, 2019	Presentation to Lheidli T'enneh community at their annual awards event

August 7, 2019	Public Open House held at Lheidli T'enneh First Nation's House of Ancestors
August 8, 2019	Draft Project Description forwarded to Lheidli T'enneh at the same time it was sent to EAO
September 11, 2019	Lheidli T'enneh provides WCOL with comments on Project Description

The discussions have evolved over the past several months, and we are now entering into formal negotiations.

The WCOL Project team has identified one other Indigenous group as potentially being affected by aspects of the Project, namely the Nazko First Nation. WCOL has contacted the Nazko First Nation and forwarded the copy of this Project Description to them.

WCOL will continue to collect feedback from the Lheidli T'enneh First Nation and other Indigenous groups through consultation and engagement processes throughout the regulatory application and review process. Based on early feedback, the following have already been identified as potential areas of interest and/or impact:

- Interests and concerns related to potential impacts on the Fraser River and its salmon fishery.
- Local area airshed concerns related to potential impacts on human health and especially, but not limited to, particulate matter ($PM_{2.5}$) and sulphur emissions.
- Concerns related to safety of the facility operation and management of potential accidents and malfunctions.
- Interest in participating in long-term economic benefits, such as investment in an equity position with the project and other opportunities.
- Interest in business and contracting opportunities related to the Project.
- Interest in employment, training and education programs related to the Project.
- Interest in participating in the EA process and other regulatory processes in a collaborative manner.
- A desire to identify areas of interest to be studied as part of the regulatory processes and participate in selection of qualified consultants or experts to study and assess these areas.

WCOL intends to continue to engage Indigenous groups to share Project information and work collaboratively with these groups to identify interests and concerns and identify approaches to mitigate potential adverse effects of the Project. These objectives will be achieved through timely communication of Project progress to the identified Indigenous community Project liaison; opportunities within the regulatory process to collect feedback, such as during Valued Components Selection and when preparing the submission in response to draft Application Information Requirements; general Project updates; and additional Indigenous community Project information-sharing sessions and participation in community events as may be requested by Indigenous groups.

WCOL understands that the Section 11 Order will identify and delegate procedural aspects of consultation to WCOL, specific to the EA process. Activities conducted following the Section 11 Order will follow the Indigenous Consultation Plan, which will be developed in alignment with the requirements outlined in the Section 11 Order.

5.2 Engagement with Stakeholders

This section summarizes the WCOL Project team's approach to engaging and consulting with local stakeholders, including local businesses and associations, other interested parties and various levels of government and describes WCOL's engagement efforts to date.

WCOL has worked with local community leaders to develop a preliminary list of stakeholders and community organizations that may have an interest in the Project and related facilities. This list will continue to be expanded and developed as WCOL continues to meet with members of the community to discuss the Project.

Table 5.2: Identification of Stakeholders.

Identification of Stakeholders
Local, Provincial and Federal Governments
City of Prince George
Local Members of the Legislative Assembly
Local Members of Parliament
Regional District of Fraser-Fort George
Community Organizations
University of Northern British Columbia (UNBC)
College of New Caledonia (CNC)
Northern Health
Prince George Airport Authority
Prince George Naturalists
Prince George Running Club
People's Action Committee for Healthy Air (PACHA)
Prince George Airshed (PG Air)
Northern Development Initiative Trust (NDIT)
Prince George Chamber of Commerce
Community Futures
Innovative Central Society

Identification of Stakeholders
Aboriginal Business Development Center
IMSS Immigrant and Multicultural Services Society
Independent Contractors and Business Association (ICBA)
Northern Regional Construction Association (NRCA)
Recycling and Environmental Action Planning Society (REAPS)
Rotary Club of Prince George
Kiwanis Prince George
University Hospital of Northern Prince George (UHNBC)
Community Associations (Blackburn, College Heights, Crescents, Hart, South Bowl, West Bowl)
Tourism Prince George
School District 57 (Prince George)
Spruce City Wildlife Association (SPWA)
British Columbia Employment Standards
Emergency Services
Prince George Fire Rescue
British Columbia Ambulance Service
Prince George RCMP
British Columbia Emergency Health Services (BCEHS)
St. John Ambulance
Fisheries
Freshwater Fisheries Society of BC
Canada Fisheries and Ocean

5.2.1 Engagement Activities to Date

WCOL initiated engagements with stakeholders and community organizations in February 2019. The primary purpose of the engagements to date has been to introduce the scope and execution strategy of the proposed Project and to gauge the general level of support and also the potential areas of concern within the community. During these engagements, WCOL has introduced stakeholders to the full scope of the Project and its associated facilities and businesses (see Section 1). Stakeholders whom WCOL has engaged to date on the Project are listed in Table 5.3 together with a summary of the engagement activity.

Table 5.3: Stakeholder Engagement.

Stakeholder	Date	Activity
City of Prince George	4-Feb-19 and subsequently	Presentation to Mayor and staff to introduce information related to the Project. Multiple follow-up meetings with City staff.
Northern Development Initiative Trust	5-Feb-19	Presentation to Northern Development Initiative Trust leadership to introduce information related to the Project.
Prince George Local Contractors	28-Mar-19	Afternoon workshop with over 20 local fabrication and construction contractors. Presentation to introduce information related to the Project, followed by informal question & answer and one-on-one discussions. This kicked off the process to solicit local contractor capability through a Request for Information (RFI) process.
CN Rail	11-Apr-19	Teleconference call with Western Canada leaders and managers to introduce the Project and solicit input on prospective locations and product movements.
Prince George Local Contractors	April and May 2019	Request for Information issued and responses received from over 40 local contractors on their capabilities relative to the Project scope. Information is being used as the basis for forming construction execution plan.
Prince George Local Contractors	29-Apr-19	Afternoon workshop with close to 40 local fabrication and construction Contractors. Presentation made to propose execution strategy and share early results of RFI process. Followed by informal question-and-answer session and one-on-one discussions.
CN Rail	30-Apr-19	Met with local Prince George leadership to review site location and feasibility of moving product by rail movement.
City of Prince George	24-June-19	Presentation to City Council to introduce information related to the Project.
College of New Caledonia	25-Jul-19	Met with College leadership to discuss the current education programs available and the types of skills and long-term employment required to support the Project.
Northern Development Initiative Trust	7-Aug-19	Follow-up meeting on strategy to develop and increase the capacity of local Prince George contractors to support fabrication and construction of facilities for the Project.
Prince George Airport Authority	7-Aug-19	Met with Board members and leadership to introduce the Project.

Stakeholder	Date	Activity
People's Action Committee for Healthy Air	7-Aug-19	Met with air quality advocates from the local community to introduce the Project and collect early input on areas of interest related to the Project and related facilities.
Prince George Public Open House	7-Aug-19	Two open events were held for open public participation. Presentation to introduce information related to the Project followed by an open question-and-answer session.
Prince George Naturalists	8-Aug-19	Met with local members of the naturalist group responsible for trail and park development in the area to introduce information related to the Project and collect feedback on potential areas of interest related to the Project.
Northern Regional Construction Association	8-Aug-19	Met with local membership to introduce information related to the Project, discuss their interest in potential opportunities for local members and collect feedback on potential areas of interest related to the Project.
Independent Contractors and Businesses Association	8-Aug-19	Met with local membership to introduce information related to the Project, discuss their interest in potential opportunities for local members and collect feedback on potential areas of interest related to the Project.
Economic Development Introduction	8-Aug-19	Met with representatives of local economic development organizations, including Community Futures, City of Prince George, Innovation Central Society, Aboriginal Business Development Centere, Northern Development Initiative Trust, Prince George Chamber of Commerce and IMSS Immigrant and Multicultural Services Society to introduce information related to the Project.

WCOL has also completed a significant engagement process with local suppliers, fabricators and constructors ("contractors") to introduce them to the construction efforts and long-term plant maintenance and sustaining capital requirements of the Project. These early engagements are required to identify the current capabilities of the local contracting community and also to determine where investment is required to expand these capabilities to effectively support the Project. WCOL is committed to efficiently maximizing local contractor capabilities during the construction phase of the Project to achieve a competitive capital cost for the Project and related facilities while also benefiting the local economy. This engagement process has consisted of a series of group presentations (see Table 5.3) and one-on-one meetings with over 40 additional contractor companies not listed in Table 5.3.

Key Areas of Interest

Through these early engagements with stakeholders and community organizations, WCOL has identified early areas of interest related to the Project:

- Support for the economic diversification in interior BC and the long-term employment opportunities during the operations phase of the Project, especially in light of the recent downturn in the forestry sector.
- Support for the local job creation and economic boost related to the proposed WCOL execution strategy and the maximization of local contractor involvement during the construction phase of the Project.
- Support for WCOL's positive approach of engaging with the community early.
- Local area airshed concerns related to potential impacts on human health and especially, but not limited to, particulate matter ($PM_{2.5}$) and sulphur emissions. These concerns are related to the "bowl" created by the Fraser and Nechako Rivers and inversions that trap pollutants, and what emissions the Project would add to this system.
- Interests and concerns related to potential impacts on the Fraser River as a result of water use by the Project.
- Concerns about increased rail traffic related to the transportation of hydrocarbons and finished products as a result of the Project.
- Concerns about increased traffic during the construction and operation phases, especially in the Prince George industrial park.
- Location of the Project area within the "bowl" (related to air emissions concerns above) and the potential visibility of the Project from the neighbourhood known as College Heights. There have also been off-setting comments from the public that they support the location of the facility on previously disturbed land allocated for industrial use.
- Concerns related to safety of the facility operation and management of potential accidents and malfunctions.
- Interest in participating in long-term economic benefits, such as investment in an equity position with the project and other opportunities.
- General interest in wanting to receive more detailed information related to the Project and to better understand the facilities and the operational requirements of the Project.

WCOL will continue to expand and develop this list through future engagement efforts related to the Project. Feedback received will be used in the scoping of existing conditions studies for the Project, identification and selection of Valued Components, and development of approaches to mitigate potential adverse effects of the Project as well as associated monitoring programs.

5.2.2 Planned Activities

The WCOL Project team is highly committed to ongoing engagement and consultation with potentially affected stakeholders and local community organizations. The Project is largely introducing a new industry into Prince George and central BC and one of the keys to success is to have an highly informed and supportive community, requiring a continuous effort to share the Project scope and to work collaboratively to identify measures within the Project which mitigate or address potential adverse effects of the Project.

Key planned engagement activities include:

- Holding general public Open Houses to share general Project information and then as areas of potential concern are identified, discuss in more detail actions to mitigate and address community concerns.
- Continuing to identify and meet with interested and potentially impacted stakeholders and community organizations.
- Holding contractor workshops and one-on-one meetings to further refine WCOL's execution strategy.
- Sharing Project information through the WCOL website, social media, radio and other media as appropriate.
- Continued engagement in relation to the regulatory process.

WCOL strongly believes that the long-term operational and commercial success of the Project depends on the support of the Prince George community and is therefore committed to developing long-term, trusting and positive relations with the community. The Project and related facilities will be a significant contributor to and diversify the local economy and will become a major component of the local community fabric for decades to come.

Engagement through the regulatory process will be guided by the Public Consultation Plan, which will be developed pursuant to the requirements outlined by the Section 11 Order issued by the BC EAO.

5.3 Engagement with Government and Regulatory Agencies

WCOL has initiated engagement with a number of regulatory agencies and government ministries and departments throughout 2019 (Table 5.4) and this list will continue to be updated throughout the Project planning and regulatory planning processes. WCOL has established a collaborative working process with BC EAO to support the EA process and intends to continue to work closely, openly and collaboratively with BC EAO and the Working Group for the duration of the EA process.

Table 5.4: Engagement with Government Agencies.

Organization	Engagement to Date
BC Environmental Assessment Office	Preliminary discussions initiated in May 2019 to review all related facilities and discussions related to the application requirements
BC Oil and Gas Commission	Preliminary discussions initiated in June 2019 to review all related facilities and discussions related to the application requirements
BC Ministry of Environment and Climate Change Strategy	Preliminary discussions with local Prince George Director to review related facilities and discuss proposed path forward for applications
BC Ministry of Environment and Climate Change Strategy	Preliminary discussions with Climate Action Secretariat and Clean Growth Branch to review expected GHG emissions associated with the Project
BC Ministry of Energy, Mines, and Petroleum Resources	Preliminary discussions through 2019 to introduce the Project and related facilities, the value-add opportunity and feedstock for the Project
BC Ministry of Jobs, Trade and Technology	Preliminary discussions through 2019 to introduce the Project and related facilities and initiating discussions related to the capability of Prince George to supply the skills and services required for the Project
BC Hydro	Initial discussions to introduce the Project and related facilities and potential to utilize grid power to lower GHG emissions intensity for all related facilities

WCOL has engaged with the elected officials whose ridings are affected by the proposed location for the Ethylene Project to provide an overview of the Project and related activities and to seek feedback related to the Project:

- Shirley Bond, Prince George-Valemount, BC (Member of the Legislative Assembly), Liberal
- Mike Morris, Prince George-Mackenzie, BC (Member of the Legislative Assembly), Liberal
- Hon. Bob Zimmer, Prince George-Peace River-Northern Rockies, BC (Member of Parliament), Conservative
- Hon. Todd Doherty, Cariboo-Prince George, BC (Member of Parliament), Conservative

6 Closing Remarks

West Coast Olefins Ltd. (WCOL) is proposing to develop an Ethylene Project (Project) that will utilize low-cost, abundant ethane extracted from natural gas in the existing Westcoast Pipeline (by Natural Gas Liquid Recovery Plant) to generate 1 million tonnes per year of ethylene product. The ethylene will be sold to a third-party Ethylene Derivative Plant to convert the ethylene into polyethylene and possibly mono-ethylene glycol, for export to Asian markets. The Project will also produce coproducts, including mixed C3 and mixed C4 hydrocarbons, Aromatic Concentrate, and Pyrolysis Fuel Oil, all of which will be sold to North American markets. The Project will create significant value to existing natural gas produced in BC, generating additional revenue for natural gas producers and local and provincial governments. The proposed location for the Project is on an existing industrial site within the City of Prince George.

The Project is estimated to cost between $2 billion and $2.8 billion, with the construction period expected to span from the spring of 2021 through the summer of 2023. The peak construction workforce is projected to reach between 2,000 and 3,000. Long-term job opportunities are estimated at 140 to 180 permanent direct employees and 25 to 50 contract employees during commercial operation. In addition to this, the local community will experience multiple indirect benefits, such as support of local services and inclusion of local institutions for training purposes.

The Ethylene Plant will be designed with latest technology and recycle/re-use strategies to minimize safety incidents, lost productivity, energy consumption and potential atmospheric emissions. The Project will utilize hydrogen-containing offgas produced by the Plant for the majority of the Plant's fuel requirements, resulting in a clean-burning fuel that will emit no odour and negligible particulate matter. The combination of new technology, a clean fuel source and use of electricity sourced from BC's existing grid will make the WCOL Ethylene Project a best-in-class environmental performer.

The industrial site that will contain the Project Area is located close to existing utilities and amenities including developed access roads and a nearby BC Hydro power supply. Minimal land disturbance is expected to occur during the development of the land or the construction of utility tie-ins.

WCOL understands the importance of engaging early and often with parties who may be affected by or have an interest in the Project, including local community groups, regulatory agencies and Indigenous groups. WCOL is committed to ongoing consultation with these parties, and we believe that by continuing to identify and engage with potentially affected groups we will succeed in managing the concerns of all interested parties throughout the lifecycle of the Project.

Potentially affected surrounding environment and land has been identified, and WCOL will undertake the proper application and permitting processes and consult the designated regulatory agencies as required.

In summary, WCOL intends to work closely with stakeholders to responsibly develop a Project that delivers a globally competitive and environmentally best-in-class facility, provides value-add to a western Canadian resource and diversifies and strengthens the local and BC economy.

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8 Appendices

Appendix A: Environmental Regulatory Assessment Requirements

Table 8.1 identifies Environmental Assessment thresholds that are applicable to both the NGL Recovery Plant and the Ethylene Plant, as identified in BC and Canadian regulations.

Table 8.1: Comparison of NGL Recovery Plant and Ethylene Project Scope Against BCEAA and CEAA 2012 Threshold Guidelines.

Activity/ Component	BC Environmental Assessment Act	Canadian Environmental Assessment Act, 2012
Energy Storage	Permanent working storage volumes associated with the integrated WCOL project are below the threshold volumes.	Permanent working storage volumes associated with the integrated WCOL project are below the threshold volumes. Note: the federal threshold is a more stringent criterion than the BC regulation.
Natural Gas Processing	The WCOL NGL Extraction facility has the design capacity to process 58 million standard cubic metres per day (Sm^3/d) (threshold is less than 5.6 million Sm^3/d). However, all gas in the Westcoast Pipeline has already undergone processing in field gas plants. WCOL understands that this threshold is intended to apply to raw (potentially sour) gas processing and does not apply to gas already meeting pipeline specifications.	Natural gas from the pipeline has already been sweetened and therefore this threshold does not apply.
Water Diversion Project	WCOL's estimated raw water intake from the Fraser River is well below the diversion guideline of 10 million m^3/year.	WCOL believes that this guideline is not applicable to this project as this guideline is only applicable to inter-basin transfers.
Railway	WCOL is well below the threshold for new rail infrastructure.	WCOL is well below the threshold for new rail infrastructure.

Appendix B: NGL Recovery Plant Scope

The purpose of the NGL Recovery Project is to recover C2+ NGL from the Westcoast Pipeline and then separate this mixture of NGL into separate ethane, propane, butane, and condensate products, with each product meeting exacting specifications.

This Project consists of 2 Plants: the NGL Extraction Plant and the NGL Separation Plant. The 2 Plants will be located at separate sites:

- The NGL Extraction Plant will process rich natural gas from Enbridge's Westcoast Pipeline, removing NGLs (ethane, propane, butane, and C5+ condensate) and returning a lean, clean-burning natural gas to continue down the pipeline. The NGL Extraction Plant will be located at a site adjacent to the Westcoast Pipeline, less than 10 km from Prince George.
- The NGLs from the Extraction Plant will be sent to the NGL Separation Plant, where they will be split into 4 products: ethane, propane, butane and condensate. The ethane will be sent to the Ethylene Plant as feedstock. The propane and butane will be loaded on rail cars and sent to third-party Liquefied Petroleum Gas (LPG) marine export terminals in Prince Rupert or Kitimat for export to Asia. The condensate will be loaded in rail cars and sent to Alberta for sale into the condensate pool or could potentially be sold as feedstock to the Husky refinery located in Prince George. The NGL Separation Plant will be located adjacent to, but separate from, the Ethylene Plant on the Project Area in Prince George's industrial park.

The split of recovered NGL products is seen in Figure 8.1.

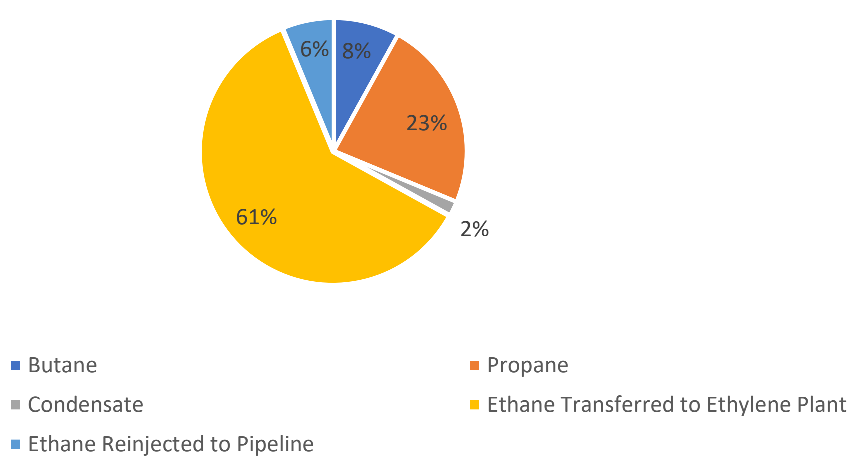

Figure 8.1: Distribution of Products Recovered from Natural Gas.

The assets that will form this Project will consist of the following facilities, equipment and activities (all capacities listed are preliminary and will be developed as engineering progresses):

- The **Extraction Plant** will be designed with a nominal capacity of 59,500,000 Sm^3/d (2.1 billion standard cubic feet per day) to roughly match the capacity of the Westcoast Pipeline. The Plant will be designed as a minimum of 2 parallel 50%-capacity trains to provide increased reliability for recovery of NGL from the Westcoast Pipeline. This facility will take natural gas from the Westcoast Pipeline and chill it to roughly -100°C so that the ethane and heavier NGL can be separated from the predominantly methane-containing lean natural gas stream in Demethanizer distillation towers. The lean natural gas will be compressed and returned to the southern leg of the Westcoast Pipeline. Design C2+ NGL volumes of roughly 16,000 m^3/d will be recovered, but the facility will be capable of higher recovery levels when the Westcoast Pipeline operates at higher NGL content. WCOL proposes to use electric motor drivers on the major Residue Gas Compressor service (in place of gas turbine drivers) to significantly reduce the GHG footprint of the Plant, pending sufficient supply and reasonable cost structure from BC Hydro. Major equipment in this plant will consist of mole sieve drier beds with direct fired regeneration heaters, heat exchangers (shell and tube, brazed aluminum cold boxes and aerial coolers), Turbo Expanders / Turbo Compressors, distillation towers, electric-driven compressors and process pumps.
- **Mixed C2+ NGL storage** will be located adjacent to the Extraction Site. The storage is expected to be buried, underground tube storage with a storage capacity of at least 7,500 m^3.
- An **NGL transfer line**, designed to transport up to 25,000 m^3/d of mixed C2+ NGL (ethane, propane, butane and condensate) from the Extraction Site to the Project Area. Routing for the Transfer Line will be determined once the location for the Extraction Site has been finalized, but WCOL will endeavour to follow existing pipeline or power line rights-of-way to minimize construction or operational impacts.
- All **utilities and infrastructure** required for the operation of the NGL Extraction Plant, mixed C2+ NGL storage and the initiating end of the NGL Transfer Line will be located at the Extraction Site.
- The **NGL Separation Plant** (located at the Project Area) will be designed with a nominal capacity of 16,000 m^3/d of mixed C2+ NGL feed (capacity to be evaluated as engineering proceeds). The facility processes the NGL sequentially through a Deethanizer, Depropanizer and Debutanizer to split the mixture into separate ethane, propane, butane and condensate products. Product ethane will be transfer to the Ethylene Plant for further value-add processing and the other products sent to storage for rail loading. Major equipment in this plant will consist of shell and tube heat exchangers and aerial coolers, distillation towers, electric-driven compressors and process pumps, a propane refrigeration system, mole sieve drier beds, caustic-based and fixed bed contaminant removal systems and direct-fired process heat medium heaters.
- **Storage facilities** for C2+ NGL feed and separated propane, butane and condensate products will be located in the Project Area. The NGL Separation Plant will also contain the storage for the Ethylene Plant coproduct storage: mixed C3, mixed C4, Aromatic Concentrate and Pyrolysis Fuel Oil. Major equipment in this system will include pressurized storage spheres or bullets, storage tanks, vapour recovery

systems and transfer pumps. Total hydrocarbon storage capacity of 15,000 to 25,000 m^3 is anticipated. Final volumes will be determined as engineering progresses. Storage facilities for coproducts from the Ethylene Plant will be operated on a fee-for-service basis for the Ethylene Plant owner and will provide services to load these products into rail cars for export of the products to petrochemical consumers either in the USGC or in Alberta. WCOL proposes that these facilities be allocated to the NGL Recovery Project, because the Ethylene Plant is estimated to produce less than 10% of the total hydrocarbon liquid volumes at the Project Area and incorporating the storage and rail loading into the NGL Recovery Project operation will be highly efficient, reducing capital and operating costs and the land disturbance required across all projects.

- **Rail loading facilities** for propane, butane and condensate products from the NGL Separation Plant and coproduct volumes from the Ethylene Plant (see previous bullet) will be located on the Project Area. Major components in these facilities will consist of connections to the CN Rail line that runs through the Project Area, rail sidings or ladder tracks capable of holding up to 500 rail cars, rail car loading stations, vapour recovery equipment, rail car maintenance / inspection facilities, weigh scales and locomotive(s) or other rail car moving equipment. Expected product volumes will result in the movement of an average of roughly 4 full Unit Trains of rail cars each week.
- **Utilities and infrastructure** required for the NGL Separation Plant, storage and rail loading facilities will be provided through a combination of systems dedicated to the NGL Recovery Project and fee-for-service utilities provided by the Ethylene Project (see Appendix D for details).

Appendix C: Ethylene Coproduct Storage

Ethylene coproducts (mixed C3, mixed C4, Aromatic Concentrate Coproduct, and Pyrolysis Fuel Oil Coproduct) will be stored within the General Hydrocarbon storage farm owned by the NGL Separation Plant. Storage requirements will be sold as a service to the Ethylene Plant by the Separation Plant. All volumes and rail car volumes in Table 8.2 are preliminary estimates and will be revised as engineering progresses.

Table 8.2: Ethylene Project Coproduct Storage.

Product	Storage Type	Purpose of Storage	Total Working Volume	Shipping Strategy
Mixed C3 Coproduct	Sphere (x1)	To provide nominally 7 days of storage for this coproduct to provide reliability to manage rail car inventories and rail system disruptions.	Approximately 1700 m^3 pressurized liquid (sphere). Volume and number of units to be finalized.	Deliver to petrochemical and refining markets by rail. 12 DOT 112 pressurized liquid (LPG) rail cars per week are expected to be loaded.
Mixed C4 Coproduct	Sphere (x1)	To provide nominally 7 days of storage for this coproduct to provide reliability to manage rail car inventories and rail system disruptions.	Approximately 1400 m^3 pressurized liquid (sphere). Volume and number of units to be finalized.	Deliver to petrochemical and refining markets by rail. 10 DOT 112 pressurized liquid (LPG) rail cars per week are expected to be loaded.

Product	Storage Type	Purpose of Storage	Total Working Volume	Shipping Strategy
Aromatic Concentrate Coproduct	Tank (x1 or x2, TBD)	To provide nominally 7 days of storage for this coproduct to provide reliability to manage rail car inventories and rail system disruptions.	Approximately 900 m^3 or 1720 m^3.storage tank (TBD). Volume and number of units to be finalized.	Deliver to petrochemical markets by rail. 11 DOT 111 liquid rail cars are expected to be loaded per week.
Pyrolysis Fuel Oil Coproduct	Tank (x1)	To provide nominally 7 days of storage for this coproduct to provide reliability to manage rail car inventories and rail system disruptions.	Approximately 900 m^3 storage tank. Volume and number of units to be finalized.	Deliver to refining markets by rail. 2 DOT 111 liquid rail cars are expected to be loaded per week.

Note: DOT – Department of Transport

Appendix D: Distribution of Utilities

Certain infrastructure and utilities will be a distributed entity between the Ethylene Plant and Separation Plant, with the utility being sold as a service to the NGL Separation Plant. The distribution of the utilities between the 2 projects is presented in Table 8.3.

Table 8.3: On-site Utility Distribution between Ethylene Project and NGL Separation Plant.

Utility	Ethylene Project (EA Application)	NGL Recovery Project (OGC Application)
Wastewater Collection/Closed Hydrocarbon Drain	• Wastewater collection, treatment, and disposal requirements will be provided by Ethylene Plant utilities on the Project Area.	• Wastewater and hydrocarbons requirements will be provided by Separation Plant utilities on the Project Area.
Fuel Gas	• Supplemental Fuel Gas Requirements for the Ethylene Plant will be provided via tie-ins to the Fortis Prince George supply pipeline.	• Fuel Gas Requirements for the Separation Plant will be provided via tie-ins to the Fortis Prince George supply pipeline.
Process Heat Medium	N/A	• Process heat medium requirements for reboilers will be provided by Separation Plant utilities on the Project Area.

Utility	Ethylene Project (EA Application)	NGL Recovery Project (OGC Application)
Instrument and Utility Air	• An instrument and utility air package will be present on the Project Area to service the needs of the Ethylene Plant. • Instrument and utility air will be sold as a service to the Separation plant as needed.	• Instrument and utility air requirements for the NGL Separation Plant will be provided via the Ethylene Plant utility service.
Utility Nitrogen	• A utility nitrogen package will be present on the Project Area to service the needs of the Ethylene Plant. • Utility nitrogen will be sold as a service to the Separation plant as needed.	• Utility nitrogen requirements for the NGL Separation Plant will be provided via the Ethylene Plant utility service.
Flare	• A flare system will be provided on the Project Area for the Ethylene Plant.	• A flare system will be provided on the Project Area for the Separation Plant.
Utility and Potable Water	• Utility and Potable water requirements will be provided to the Ethylene Plant via the Prince George municipal water supply.	• Utility and Potable water requirements will be provided to the Separation Plant via the Prince George municipal water supply.
Stormwater Containment	• A retention pond on the Project Area will provide Ethylene Plant stormwater containment requirements.	• The NGL Separation Plant may have a independent system.
Fire Protection System	• A fire water system on the Project Area will provide all fire water requirements for the Ethylene Plant. • Fire water will be sold as a service to the Separation Plant.	• Fire water requirements for the Separation Plant will be provided via the Ethylene Plant Utility Service.

Utility	Ethylene Project (EA Application)	NGL Recovery Project (OGC Application)
Raw Water Inlet and Storage	• The raw water intake and treatment systems, and storage will be provided on the Project Area to meet the water requirements of the Ethylene Plant.	N/A
Utility Boiler	• To provide the Ethylene steam requirements, a utility boiler will be present at the Project Area.	• Potential to supply excess steam from the Ethylene Plant to the NGL Separation Plant on a fee for service basis will be investigated.

Appendix E: Miscellaneous Rail Information

- Length of track to be developed on-site: Up to 15 km.
- Combined NGL Products and Ethylene Coproducts will load approximately 4 Unit Cars per week.
- Number of rail cars stored on-site: Up to 500 rail cars.

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The unaccountability case of plastic pellet pollution

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ABSTRACT

Plastic preproduction pellets are found in environmental samples all over the world and their presence is often linked to spills during production and transportation. To better understand how these pellets end up in the environment we assessed the release of plastic pellets from a polyethylene production site in a case study area on the Swedish west coast. The case study encompasses; field measurements to evaluate the level of pollution and pathways, models and drifters to investigate the potential spread and a revision of the legal framework and the company permits. This case study show that millions of pellets are released from the production site annually but also that there are national and international legal frameworks that if implemented could help prevent these spills. Bearing in mind the negative effects observed by plastic pollution there is an urgent need to increase the responsibility and accountability of these spills.

1. Introduction

Plastic material is an integral part of our daily lives and the annual production is today > 300 million tons (PlasticsEurope, 2014). Most thermoplastic articles and materials originate from virgin plastic pellets, also called preproduction pellets, beads, or nurdles. These are produced in polymeric production industries, or to some extent in recycling facilities. The pellets typically have a diameter of 2–5 mm and are regular in shape. Smaller powders, often referred to as fluff, are also produced and have more irregular shapes and sizes. The produced pellets are subsequently transported from the production site, with train, truck and/or ship to the facility where the final product is being molded or extruded from the virgin material. This material can however be lost in all steps during the production chain, from preproduction, to the final item production.

The first scientific reports to document the occurrence of plastic pellets in the environment were published during the 1970's (Carpenter and Smith, 1972; Carpenter et al., 1972). Since then plastic pellets have been found in surface water samples and on beaches all over the world (Colton et al., 1974; Gregory, 1977; Morris and Hamilton, 1974; Fernandino et al., 2015; Eriksen et al., 2013). Plastic pellets are also found on beaches that are not directly in contact with petrochemical or polymer industries. Although they can be in minority in comparison to other plastic litter (do Sul et al., 2009; Fok and Cheung, 2015) they are commonly found, showing the possibility for large scale transport.

Several species of fish and birds have shown to ingest plastic pellets (Carpenter et al., 1972; Kartar et al., 1973; Baltz and Morejohn, 1977) and although the potential risks of microplastic ingestion to marine organisms are hard to quantify, the list of species known to ingest plastic in the marine environment is currently in the hundreds (Kühn et al., 2015), and includes species from all trophic levels (Eriksson and Burton, 2003). The effects of ingestion of macroplastic debris are well documented (Browne et al., 2015; Kershaw et al., 2015). Few studies conclusively address the effects of pellets ingestion and the types and amounts of microplastics used in laboratory studies are rarely consistent with those found in the field (Phuong et al., 2016). But studies on the effects of microplastics show that they have the potential to be passed up through the food chain (Setälä et al., 2016), and the plastic particles can have physiological effects, including changes in reproduction (Sussarellu et al., 2016), metabolism (Cole et al., 2015; Lu et al., 2016) and behavior (Mattsson et al., 2014). Other studies that have focused on the propensity for plastics to act as vectors of environmental toxins find that levels of common POPs can be up to 10^7 times higher in plastic pellets than in sea water (Koelmans et al., 2016; Holmes et al., 2012). A number of studies indicate that microplastics can act as vectors for pollutants from the environment into organisms

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(Rochman et al., 2013; UNEP, 2014), but the importance of this factor compared to uptake via normal feed contamination or exposure to other naturally occurring particles in the environment is still uncertain (Koelmans et al., 2016). Additionally some of the additives used in plastic products have been shown to migrate from microplastics to biota (Rochman et al., 2013).

Plastic pollution can also lead to significant economic losses, for example through losses in revenue from tourism and the cost of beach cleaning (UNEP, 2014; Mouat et al., 2010; Leggett et al., 2014). Although these costs are based on the total amounts of plastic on beaches, pellets are commonly found during beach cleaning campaigns and thereby a contributing factor to the costs.

The occurrence of plastic pellets in the environment was linked to industrial outlets already in the 70s where researchers first started calling for precautionary measures within the industry (Hays and Cormons, 1974). Even so, a study in the river Rhine from 2015 showed that 60% of the identified plastic particles were spherules, with a possible linkage to different industries along the river (Mani et al., 2015). Similarly pellets were measured at a mean density of 693 items per 1000 m^3 in the river Danube with the highest value of 138,219 per 1000 m^3 during a heavy rainfall (Lechner et al., 2014). These were, according to a press release by a close plastic production company, at least in part due to losses at a production site (Borealis, 2014). In Austria plastic is classified as a filterable substance, and the limit for discharge is 30 mg/L. This limit, extrapolated to a year's worth of discharge amounts to 94.5 tons/year, is a threshold that researchers have questioned due to the high volumes it allows for (Lechner and Ramler, 2015). Although the actual levels that leach into the environment from the production plants are unknown a recent study in the UK indicates a national yearly loss of 5–53 billion pellets (Cole and Sherrington, 2016). The results from that study is however based on estimates on the percentage loss provided from the industry and although there are examples of studies, as mentioned above, where high concentrations of pellets have been found close to production plants there is very limited data on the actual runoff.

In order to better understand how and why plastic pellets end up in the environment a case study approach was used where we investigated the major plastic industry complex in Sweden. Although the specific volumes of pellet spills may differ from site to site there is ample evidence of their occurrence, both through present and historical studies from independent researchers and the companies themselves. As the world-wide market is dominated by a few big companies, with concentrated production facilities, although a worldwide distribution and manufacturing network, there is also reason to believe that the routines would be similar on other sites. Within the case study we therefore investigate the industries associated permits and regulations, reviewed potential environmental and economic impacts and investigated the total runoff as well as the present pellet pollution situation in the nearby area. These aspects were investigated in a multidisciplinary approach, including environmental surveillance, measurement of pellet fluxes, hydrographical mapping and modelling as well as legal studies and environmental impact assessments.

2. Case study description

In the chemical industry cluster in Stenungsund, there is a polyethylene production facility in the center, with supporting industries such as an ethylene producing cracker, and also several smaller companies involved in the handling and transport of the produced pellets. Polyethylene has been produced in Stenungsund since 1963, and the production volume has gradually increased. It is the only polyethylene production site in Sweden and the annual polyethylene production capacity in Stenungsund amounts to 0.75 Mtons (Mark- och miljödomstolen Vänersborg, 2015), which corresponds to approximately 5% of the European polyethylene demand (PlasticsEurope, 2014).

The expansion of and changes in the production has required a long row of updated and revised permits throughout the years. The current permit was approved in 2007, but the decision on some conditions was postponed because of lack of information. Since then the release of particles was not mentioned in the decisions until 2013 (Mark- och miljödomstolen Vänersborg, 2013), twenty years after the first problem formulations and legal recommendations to avoid pellet spills were provided by the US EPA (US EPA, 1992). The permit background report showed high amounts of plastic particles in the effluent and the company was assigned to investigate it further. The background material also show that the company has reported that several of the additives that are used in the plastic are classified as toxic for water living organisms (Mark- och miljödomstolen Vänersborg, 2015).

In 2014 the company issued a press release stating that "our aim is to not lose a single pellet" explaining its zero pellet loss objective (Borealis, 2014). In the company's yearly environmental report, a description of their sewage and storm water treatment was presented. The storm water drains has during recent years been led from the production site through a polyethylene separator, known as a skimmer-pit, to remove particles that float or sediment. The water is then led to Stenunge Å, a small creek running by the production site, which empties into the industrial harbor. The industrial sewage system collects water from process areas; this water is led through a density separator to separate light density liquids and polyethylene. After treatment the water is led to Askeröfjorden (Borealis, 2016) (see Supplementary material 2A for a more detailed record of the company permits).

The produced polyethylene pellets are loaded for shipping and moved from the production site by road transport but can then be further transported by boat, ferries or railroad (Mark- och miljödomstolen Vänersborg, 2015; Borealis, 2016). Records from inspections, and observations in this study, show that plastic spills have been reported in proximity to transport and storage areas as well as on sites where other companies handle waste or cleaning from the production company (Supplementary material 2B).

2.1. Description of the area

The study site is located within the Orust-Tjörn fjord system on the Swedish west coast. In close proximity, there are several important Natura 2000 areas and the shores are mainly steep and rocky interrupted by bays with beaches of protected to moderately exposed character. Along some shorelines shallow salt marsh grass meadows grazed by bird life and cattle and sheep also occur. The surface water within the fjord system has been estimated to have a residence time in the order of 40 days (Hansson et al., 2013). Organic material is transported by rivers and streams into the fjord system and although a portion of it is transported out of the area, low rates of water exchange leads to accumulations in the sub-basins (Hansson et al., 2013). The fjords inside the islands of Orust and Tjörn are not directly influenced by any larger rivers, so rather than a typical estuarine circulation the circulation in the fjords is to a large degree influenced by the stratification outside the fjords as well as local wind forcing. The main water exchanges are through the southern entrance and are caused by upwelling and downwelling of the coastal stratification (Björk et al., 2000) which is strongly related to regional wind patterns (Hansson et al., 2013). The steric pressure gradient resulting from the fresher surface waters at the southern entrance give rise to a general counterclockwise circulation (Björk et al., 2000).

Although tidal currents are relatively strong in some of the more narrow straits, the general area has weak tides (< 0.2 m amplitude). The area is however strongly influenced by the Baltic Current, which carries low-saline water from the Baltic Sea northward along the Swedish coast as well as North Sea water that joins the Baltic Current via the Jutland Current. Below and outside the Baltic Current, there also is a general cyclonic circulation of the more saline Skagerrak waters. This circulation that carries surface waters from a large part of northern

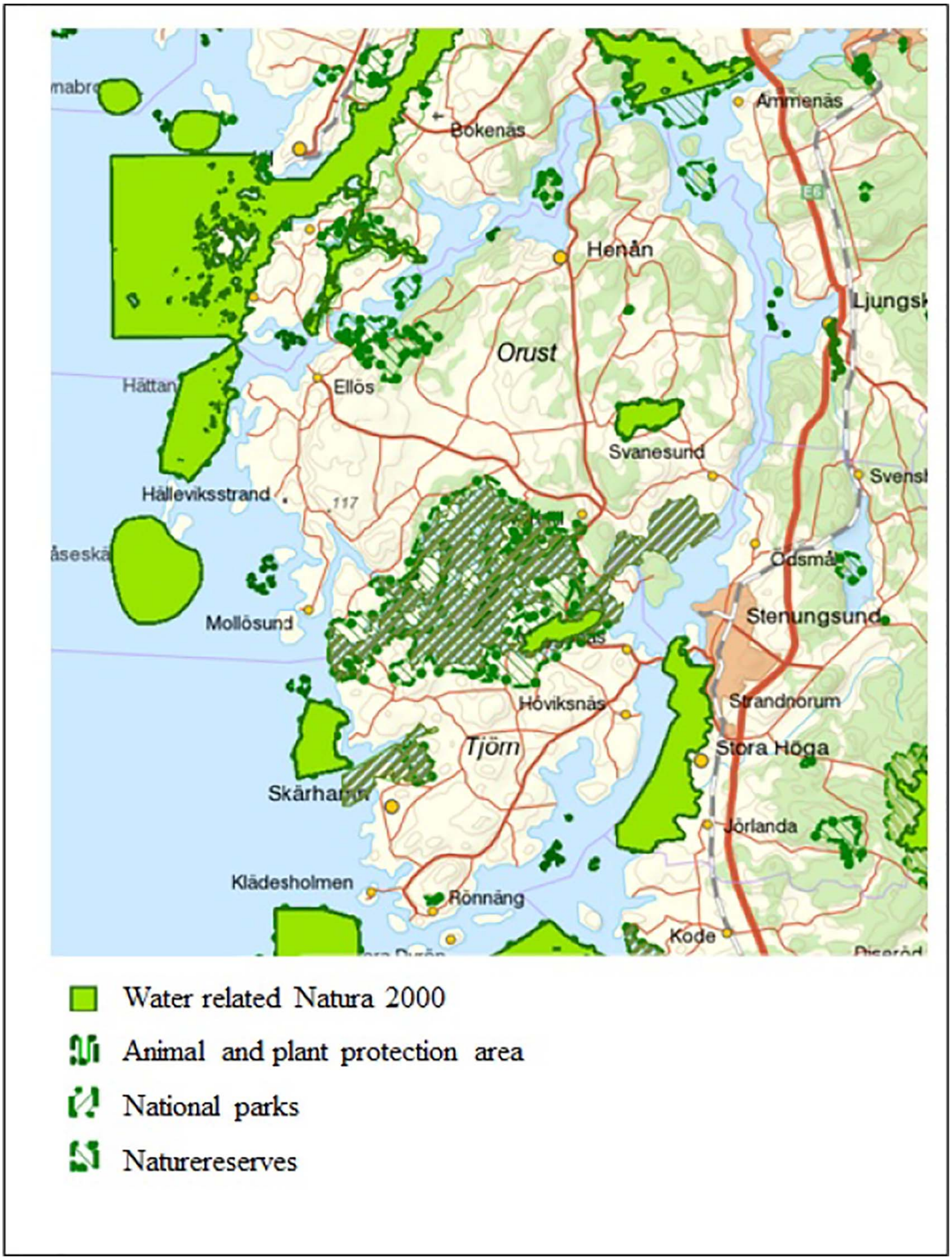

Fig. 1. Protected areas within the case study area (map adapted from Vissnet).

Europe, combined with dominating south-westerly winds that blow the surface waters onshore, has proven to cause a concentration of marine litter along the northern beaches of west Sweden including the west facing beaches of Orust and Tjörn (Strand et al., 2015).

2.2. Potential ecologic and economic consequences of pellet spills in the case study area

The durability of the pellets and their potential for long range transport result in potentially far-reaching consequences of industrial spills of plastic. Their propensity for long-range transport is however in part dependent on the characteristics of the surrounding area. Consequently in this case, a majority of the material is expected to accumulate close to the runoff areas and thereby be of local and regional concern. The Skagerrak Kattegat area is of importance from an ecosystem service perspective (Swedish E.P.A., 2009) and marine litter in Swedish waters have shown to negatively affect ecosystem services (Havs- och vattenmyndigheten, 2017).

Several protected areas are located in close proximity to the case study area (Fig. 1). In fact, 20% of the marine area in Skagerrak and Kattegat is protected (Havs- och vattenmyndigheten, 2017), but as many coastal areas; the region is also subjected to multiple stressors

(Jutterström et al., 2014). The marine environment close to the case study area is high in biodiversity (Havs- och vattenmyndigheten, 2017) and several of the important species in the area are filter feeders such as brittle stars, sponges and blue mussels (Havs- och vattenmyndigheten, 2017) which may be vulnerable to microplastic plastic spills. Specifically filter feeders have been shown to ingest high concentrations of microplastics when compared to animals employing other feeding strategies (Setälä et al., 2016). For provisioning services in Swedish waters, marine litter is expected to have a moderate negative effect on food, and for regulating services, a moderate negative effect on the regulation of toxic substances (Havs- och vattenmyndigheten, 2015). This may be of additional importance in this case as concern has been raised about the release of plastic additives and bi-products that are toxic for water living organisms from the production facility (Mark- och miljödomstolen Vänersborg, 2013).

Furthermore, the region of Bohuslän is identified as an area of national interest for outdoor life. One example is the extensive recreational fishing of brown trout in Stenunge å, where recent analyses of their stomach content have shown that 68% of the fish has ingested microplastics (Karlsson et al., 2017). The importance of recreation and tourism in the area is further mirrored in the fivefold increase in population that occurs during the summer, also reflected in the additional summertime increase in leisure boating; 27% of the guest nights for recreational boats are in the northern part of Bohuslän (Havs- och vattenmyndigheten, 2017). Although any detailed calculations on the cost that the plastic spills from industry have on recreational values are beyond the scope of this study, marine litter has repeatedly been shown to have a negative economic effect on tourism and recreation (Mouat et al., 2010; Leggett et al., 2014; Hays and Cormons, 1974; Jang et al., 2014; Botero et al., 2017). In fact, it has been estimated that marine litter in Swedish seas has a strong negative effect on ecosystem services within cultural values related to recreation and aesthetics (Havs- och vattenmyndigheten, 2015).

3. Materials and methods

To assess the current situation of plastic spills in the case study area a combination of measurements and photo documentation in the field in combination with theoretical calculations and models was performed (Supplementary material 3A). The results were then related to the legal documents, permits and policies.

3.1. Pellet discharge to surrounding waterways

Field measurements were made to assess the hourly runoff of particles from the production plant site into Stenunge Å. Sampling was performed on the 20th February 2016. A net was places so that the surface water of the river outside the production site was collected using a 300 μm mesh (See Fig. 2). The full sample was size fractionated into > 2 mm, 2–1 mm and 1–0.3 mm. The plastics in the > 2 mm fraction were manually separated from the organic material, counted, sorted according to color and weighed (Mettler Toledo). A subset of 20 pellets were then measured with Fourier transform infrared spectroscopy (FTIR, Nicolet iN10, reflection mode 64 scans) for identification purposes. Additionally the surface degradation for 10 particles was compared through FTIR-ATR (256 scans). From the smaller fractions triplicate subsamples of a few grams were taken and the number of particles/g was counted in a stereomicroscope. 25 particles from the smaller fractions were analyzed with FTIR in reflection mode (64 scans).

3.2. Dispersion of pellets

3.2.1. Theoretical dispersion in the area

In order to estimate the spread of the pellets released from the production plant, GPS-drifters were deployed. One drifter with the dimension of 11 × 21 × 7 cm and a density about 500 kg/m^3 and two drifters with the dimensions of 11 × 8 × 5 cm and density of density about 800 kg/m^3 were deployed in the end of March-beginning of April, and followed until they stranded. Wind data was retrieved from the meteorological station Måseskär. Theoretical estimates of the dispersion from the source were established based on the observed typical drifting times and distances together with earlier published estimates of surface water residence times and mean flows through the system (for a detailed description of the calculations see supplementary material for the result Section 4.2.1).

3.2.2. Field measurements on nearby beaches

In order to assess the pellet pollution level in the archipelago where the plastic industry is situated, the number of pellets on the beaches was surveyed. There are standardized methods to survey beaches for macroscopic marine litter (OSPAR Commission, 2010; Cheshire and Adler, 2009). In these guidelines, a 100 m stretch of beach from the water to the end of the beach should be completely surveyed for an extensive range of standardized items. Pellets are categorized in the databases of UNEP and OSPAR, but not required to be counted, only documented as a yes/no. Beach dynamic processes have been shown to affect the distribution of the pellets (Moreira et al., 2016) and to count pellets on 100 m beach is extremely time consuming for a normal sand beach, but for the rocky archipelago of the Swedish coastline with small irregular bays, this practice is not even applicable. Our method of choice was to manually search and count the number of pellets found per unit hour of searching. The same person was carrying out the search surveys to maximize comparability. Although we acknowledge the method not to be linearly quantitative, and to some extent is influenced by the characteristics of the specific beaches, it more than fulfills the objective of the study; to assess the relative abundance density of pellets on beaches in the case study area.

3.3. Legal aspects

Relevant laws and regulations were reviewed through looking through the company permits, scientific literature on the topic and through searching for relevant cases brought up in the European commission. The legal framework was then examined through an established methodology (Gipperth, 1999; Westerlund, 2003), analyzing the relationship between environmental objectives, legal requirements and enforcement. Legal requirements were determined by the analysis of traditional legal sources such as legislation and case law. The analysis of the permits and decisions made by courts and authorities provides an understanding of how the implementation of general rules of conduct is applied and enforced.

4. Results and discussion

4.1. Pellet runoff to surrounding waterways

During a time span of 1 h (date 2016-02-20), 4086 pellets were caught by a net that spanned the whole transect of the creek, collecting the surface water. Analysis confirmed that both new and older degraded plastics were present in the collected sample (Supplementary material 4A).

Using the water flux on the sampling day (0.293 m^3/s, obtained via the Swedish Meteorological and Hydrological Institute, vattenwebb.smhi.se), we calculated that that the concentration of pellets in the creek was about 3870 pellets/1000 m^3. This can be compared with the average density of 727 pellets and spherules/1000 m^3 measured in the Danube.

During the sampling occasion in Stenungssund, the rainfall at the nearby Kamperöd measurement station (SMHI) was 13.5 mm during the 24 h period of the sampling day, which corresponds to a 94% fractile for that station; i.e. on average it rains more than this on 22 days

Fig. 2. Sampling setup for measuring the total pellet runoff during 1 h. On the upstream side of the small bride (A) wooden pieces were placed so to lead the surface water into one of the tunnels and on the downstream part (B) a net was attached which led all the material floating on the surface to a collection sock at the end.

of a year, which means that this was a large but not extreme rain fall. No overflows of the storm water holdings in the production area were reported (Borealis, 2017) hence the measured release is expected to be normal for the time and weather conditions. In order to estimate the average flux, four separate calculations based on different assumptions were made (Supplementary material 4B for calculations):

1) Flux threshold, where the pellets were assumed to remain in the banks until the water rises. This assumption would give 23,500 pellets/day
2) Constant concentration of pellets related to the mean flux; gives 70,000 pellets/day
3) Rain assumption, pellet spills between rainfalls; 8200 pellets/day.
4) Constant concentration of pellets in the creek, i.e. the measurement is representative of a continuous release; 98,000 pellets/day

Although daily variations may be large, these different assumptions would correspond to an annual release between a minimum of 3 million and a worst case scenario of 36 million pellets. The total weight of the pellets in the sample was 99.28 g resulting in an average weight of 0.02 g/pellet. From the above calculated values, we can thereby deduce that the annual weight of the spilled pellets would be between 73 and 730 kg. However, when smaller fractions down to 300 μm (Fig. 1B) were included in the measurements of hourly runoff, the total particle count was over 500,000 particles. This indicates an approximate hundredfold increase in particle release compared to the release of pellets alone. The majority of the particles (78%) were translucent to white fluff, although fragments (> 21%) and pieces of foil (1%) were also present. The weight of these smaller particles was low, with an average mass of 0.0007 g, but if this weight was extrapolated to the above calculated values for the average flux of pellets, and multiplied with a hundred to match the relative particle counts, the approximate annual release would be between 200 and 2600 kg. The total weight of the particles in the smaller fractions is thereby approximately three times the weight of the pellets, which highlights the importance of including spill of material in the smaller fractions. When included, the total release of plastic particles above 300 μm from the production site would be between 300 and 3000 kg annually.

Notably, these numbers do not account for overflows, which were reported to occur twice in 2016, and which in the Danube has been associated with the release of large volumes of pellets (Lechner et al., 2014). During site inspections of US plastics production plants in the nineties it was noted then that existing barriers was not effective during intense rainfalls (US EPA, 1992). Our measurements neither account for the spills observed on sites other than the production area, such as cleaning facilities, ports or transport and storage areas (Supplementary material 4C). Additionally, only 5% of the European polyethylene production occurs at this site and similar conditions are to be expected on other production locations.

Most of the both particle abundance and volume were below 1 mm with increasing counts for smaller sizes (Fig. 3). It is therefore likely that a smaller mesh size would show an even higher level of particle runoff from the production site. A quantitative sampling for smaller sizes would however require a different sampling protocol as smaller particles might be more evenly distributed through the water column, whereas pellets are expected to float at the surface. Due to these differences in distribution patterns, dependent of particle size the particles below 1 mm may also be underestimated. Furthermore, the spread of the fluff and the fragments may be harder to assess in samples taken further away due to their irregular shapes (Fig. 1).

Previous studies that have assessed pellet spills have primarily been based on estimates provided from the industry (Cole and Sherrington, 2016) and rarely account for smaller fractions. These results are therefore unique as they provide onsite measurements of pellet runoff. They also highlight the importance of including the smaller fractions in

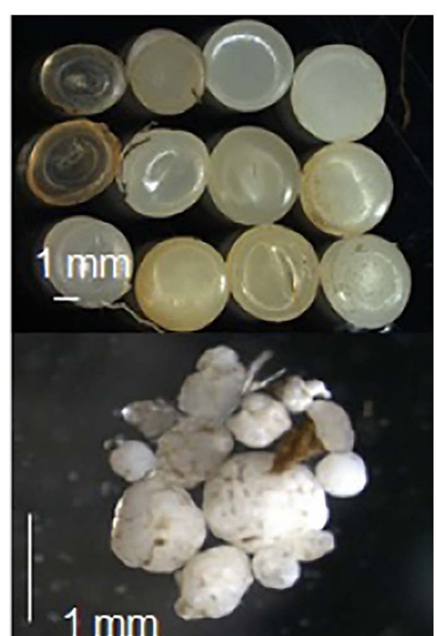

Fig. 3. Typical particles found in the runoff from the production plant. The upper image shows translucent pellets and the lower image shows fluff and fragment found in the lower size-fractions.

future studies.

4.2. Dispersion of pellets

4.2.1. Theoretical calculation of the dispersion from a local source

In a scenario where the pellets that are released from the production site are not assumed to beach in the area a steady state would be reached after 50 days, in accordance with the water exchange within the fjord. If the more conservative estimate of number of released pellets (3 million pellets per year ≈ 0.1 pellets/s) is used, the concentration in the fjord would in that case be $1 \cdot 10^{-2}$ pellets/m^2 and the total number in the system would be 0.5 million pellets (Supplementary material 4D).

However, the drifter studies indicate that the typical floating distances are of order 0–5 km with most typical distances of order 1–2 km. After that, the drifters land on the surrounding beaches (Supplementary material 4D). It remains unclear when and how the drifters get back into the fjord from the beach, which would require further studies.

For a more realistic estimate of pellet dispersion and the concentration of pellets within the fjord system the beaching needs to be included in the calculations (Supplementary material 4D), and with this approach we find that pellets remain in the fjord area. The model is built on general assumptions on drift and is thus applicable on other location. The parameters have however to some extent been fitted to local conditions (fjord with complex topography with rocky shores and small bays). The drift of surface particles tends to follow the wind, but here the general wind direction is not aligned with the fjord (while in practice it often follows the fjord direction more closely than wind outside the fjord). Taken together with the drifter study we find it reasonable that particles travel a few km's before reaching a beach (this was partly based on a crude estimate on the probability of wind directions for the area). Using the conservatively estimated release of 0.1 pellets/s would after 10 years result in 31 million particles on the surrounding beaches. The concentration would be highest at the release site with 1500 pellets/m (750 pellet/m beach) and decrease linearly to 0 pellets/m about 40 km from the release site. With a continued release of pellets the concentration would increase further and the pellets would also spread further with time, although the calculations imply that these increases would not be linear (Supplementary material 4D). None of these estimates include sinking which would require further studies. These measurements and calculations highlight the importance of including beaching and re-mobilization when studying plastic distributions, especially when the sources are not situated directly at open coasts.

4.2.2. Observed pellet pollution on nearby beaches

The relative amount of pellet pollution was higher in close proximity to the production site (Fig. 4), although a higher concentration was also found south of the harbor where a lot of the material is known to be handled for transport. The highest amount was found at the mouth of Stenunge å, where counting was limited to 2 min (instead of an hour) during which 7030 pellets were found. The corresponding values for 1 h of beach count was 211,000. High concentrations were found in several of the surrounding protected areas. The abundance on surveyed beaches decrease with increasing distance from the industrial area, but it is notable that relatively high pellet abundance can be found in all regions to the north in the fjord system, some 35 km away. The color signature of the pellets that is found in the Stenunge Å creek (white, black, blue and yellow) is also found in resembling proportions in the archipelago. When sampling beaches on the west coast of the island Orust or away along the coast, other color signatures are found possibly as a result of long range transport (Supplementary material 4E).

4.3. Legal framework and policies

There are no existing international frameworks or European (EU) laws which specifically address plastic pollution due to industrial spills. It is also rare that pellet spills are directly regulated on national levels. There are however exceptions and it should be noted that the US EPA provided regulation recommendations to specifically prevent plastic spills already in the nineties (US EPA, 1992) and today there is a Clean Water Act in the USA, where the California Water Code (chapter 5.2) states that the state board and the regional boards “shall implement a program to control discharges of preproduction plastic” (CaliforniaLaw, 2007). However, most countries today have some type of legislation aiming at generally protecting the environment from pollution. At international and EU level there are also several legislations more or less applicable dependent on where in the lifecycle of the material and where the plastic spill occurs (for EU in part reviewed in European Commission (2013) and Steensgaard et al. (2017)).

During production, transport and usage, some of the more relevant regulations are the Packaging Directive (Directive 2008/98/EC, 2008), REACH (Regulation (EC) No 1907/2006) and the Industrial Emissions Directive (Directive 2008/98/EC, 2008). If shipped at sea, the release of the pellets would be prohibited due to Annex V of the MARPOL Protocol of 1978 (IMO, 1973), a treaty that was set up to prevent pollution and dumping of garbage from ships. If the pellets (loss) are considered as waste materials, it's appropriate to consider the Basel convention (UNEP, 1989) and in relation to EU the European Framework directive on waste is also important as it identifies an extended producer responsibility (article 8) as a key principle for waste management.

In 2014, Franz Obermayr submitted a question to the European commission regarding the pollution of European rivers and lakes with plastic pellets (European Parliament, 2014). The question was divided in 6 parts, mostly concerning how the commission was planning to address the raw material that had earlier that year been shown to end up in the Danube. The commission answered that the member states are responsible to comply with suitable environmental regulations and also mentioned the waste framework directive and the industrial emissions directive (Directive 2010/75/EU, 2010). Moreover marine litter is identified as one of the key factors affecting the status of the environment and member states are demanded to take sufficient measures to decrease the quantities of marine litter to levels not causing harm to the coastal and marine environment, according to the European Union Marine Strategy Framework Directive (MFSD) (European Union, 2008).

In excess of international conventions UNEP and NOAA in 2011 initiated the Honolulu strategy, a framework to reduce the impacts of marine debris. One of the proposed actions on this strategy, directed towards land based sources, is the development and implementation of regulatory tools to avoid release of pellets, when voluntary commitments are not sufficient (NOAA/UNEP, 2011). The Honolulu strategy further guides the work of the voluntary global partnership on marine litter (GPML) and is recognized within the Manilla declaration (UNEP, 2012).

In Sweden the Swedish Environmental Code regulates all handling of plastic pellets during the entire lifecycle, from pellet to product to waste. A set of rules of conduct (Chapter 2 in the Environmental Code) require all operators independent of the actors size and type, to take precautionary measures, by e.g. getting sufficient knowledge about the risk for human health and the environment, locating their activity in a place causing the least environmental impact, adhering to the substitution principle through, when applicable, replacing chemical products and chemicals with alternatives that have fewer negative environmental impacts, and using best available technology. These rules apply to all activities as long as it is not proven unreasonable when comparing benefits with costs. In relation to protected areas, like Natura 2000 areas or nature reserves, the level of demanded precautions is set higher.

When submitting an application for a permit (which is mandatory

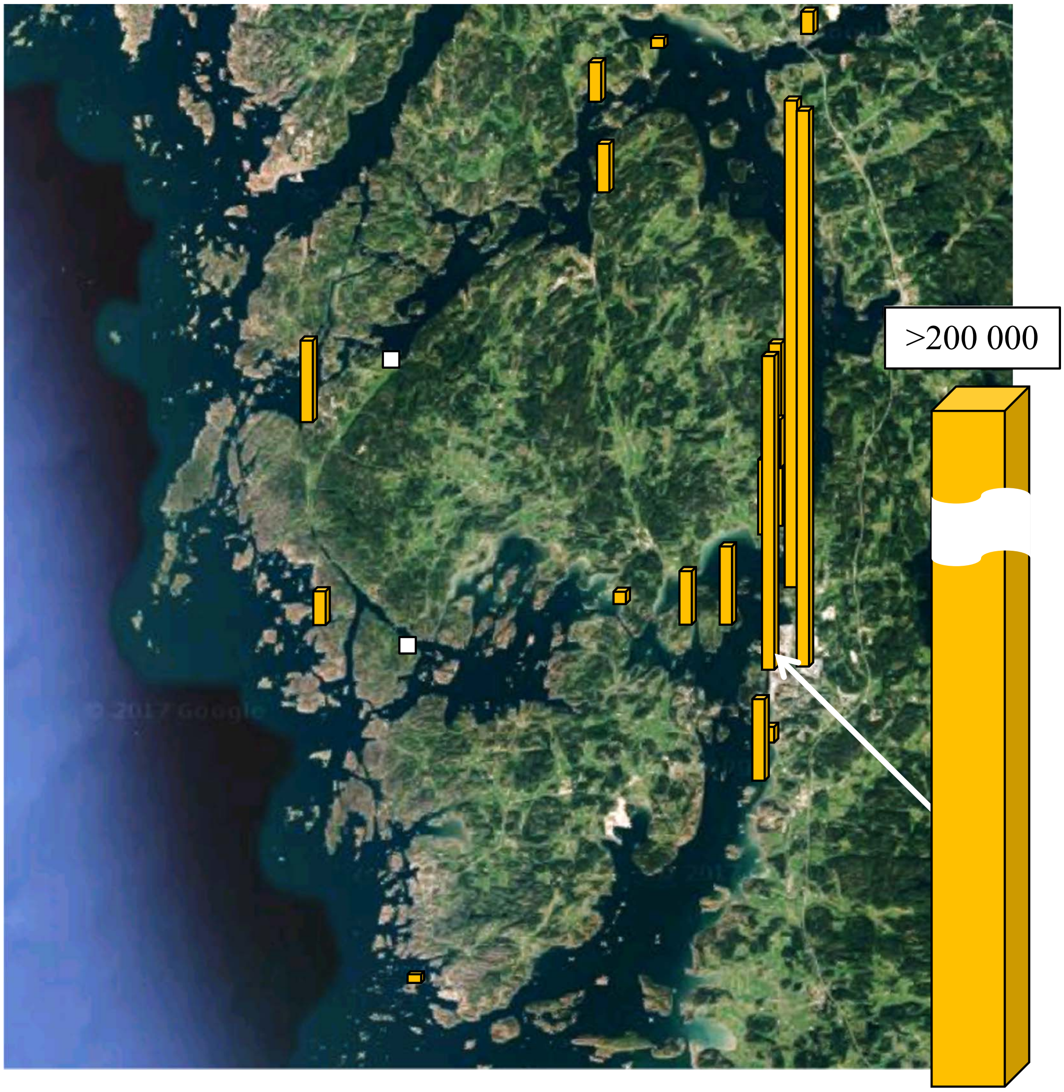

Fig. 4. Results from measurements of pellets on beaches in the area. The heights of the yellow bars are relative to the number of pellets found per hour and person. White squares show examined sites where no pellets were found (Map adapted from Google maps). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article).

for starting or changing larger industries and activities presumed to have an environmental impact), the operator needs to prove that the activity can fulfill the general rules of conduct. Conditions for a permit are set in order to assure this fulfillment and are controlled by both the activity itself and a supervising authority. In case a producer of pellets chooses to expand their production a new permit is necessary (See supplementary material section 2A for a chronological detail of the company permits). In order to enforce the general rules of conduct in relation to smaller activities the supervising authority may issue an injunction demanding the activity to fulfill more specific requirements.

It can therefore be stated that there are several frameworks, on international, European and national levels in place that should hold the different actors involved responsible for preventive measures, and accountable for extensive spills of plastic into the environment. The suitable policies and legislations have, however, not been sufficiently implemented and enforced. In the case study the company permits only recently started to mention and regulate pellets. The lack of specific conditions relating to plastic spills has allowed a continuous release of plastic materials. This could in part be explained as a consequence of treating plastic materials as though they were ordinary benign products, similar to natural bulk commodities, and persisting in doing so even in the face of an increasing body of scientific data that show several potential harmful consequences of plastic litter for environmental and economic values.

5. Conclusions

In this work we make a first estimation of the total release of preproduction pellets from a production site to the surrounding environment and find it to be between 3 and 36 million pellets annually. We also show that if smaller fractions of plastic particles, down to 300 μm were included, these numbers were multiplied with a factor of hundred and the mass by a factor of three. Extensive occurrence of pellets on regional beaches are wide spread although declining further away from the industrial complex area but still extend several tenths of km in the complex archipelago. Furthermore, we show documentation of spills around areas of subcontracted companies involved in transport, storage, cleaning and waste management. The release is expected to be a consequence of inadequate precautions during production, loading, transport and handling of the material. Although the quantity of the spills may vary at different locations this case study is likely to be representative of the processes that have led to the documentation of pellet pollution on beaches and in water samples globally. Due to recent changes in the production company permit, they have recently installed

10 μm filters in the drains on the premises to avoid further pollution. Although the effect of the installed filters remains to be investigated, this shows that there are now technical solutions readily available to prevent pollution which could prove to be efficient on other production sites. However, it is important to include handling practices and preventative measures at sites where downstream actors handle the materials as well.

The cumulative historical pollution, here indicated by the presence of aged particles, remains clearly mirrored in the surrounding areas where they may have negative effects on ecosystem services and biota. While the full impact of this type of pollution is currently under investigation by the scientific community, and effects are not yet fully elucidated, we cannot ignore the hazardous nature of pellets and their potential to cause harm to the environment.

There is a regulatory framework in place, on international, European and national levels, that if implemented could to a high degree prevent these spill or leakage events. However, as seen in the study by Lechner and Ramler in Austria (Lechner and Ramler, 2015), as well as in the current case study, these regulations, laws, and policies have not been adequately enforced on industrial spills of microplastics. These results therefore highlight the importance of addressing plastic spills from industry through existing regulations and regular inspections. It also indicates a systematic error associated with plastic pollution where, even though the pollutants can visually be seen, we as a society still fail to react.

Polyethylene and other types of plastic materials are produced in many other places, and there are several different companies involved in the production and transportation of plastics. The authors therefore recommend that spills of plastic during transport, loading, storage and production in industrial settings be specifically included in control programs and permit conditions. It is vital that this applies to all companies involved in the handling of the material to increase the responsibility for prevention and the accountability following unintentional plastic spills.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.marpolbul.2018.01.041.

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Mini Review

Occupational Diseases in the Petrochemical Sector and Offshore Upstream Petroleum Industry

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Abstract

In this mini-review occupational diseases (ODs) in the offshore oil and gas industry and the petrochemical sector are discussed. A disappointing number of publications during half a century yields a picture of hearing noise damage,musculoskelatal disorders (MSDs), debated cancers and dermatitis as main ODs. Crucial information about exposures at work places, working history and life styles to establish causal relationships is missing. Little attention is paid to job stress and mental health, addictions and COPD at the work place.

Introduction

Chemicals are used extensively both in industry and in our daily lives. Occupational disease (OD) refers to any disease contracted as a result of exposure to factors arising from work (ILO 2011)-(1). Diagnosis of OD requires establishment of the causal relationship between exposure in a specific working environment or work activity and a specific disease and the disease occurs among exposed persons with a frequency above the average morbidity of the rest of the population. The list of ODs prepared by the International Labour Organization (ILO) has four main groups [1]. ODs caused by exposure to agents arising from work activities (such as chemical, physical and biological agents), ODs by target organ systems occupational cancers and other diseases. Chemical agents account for 41 of the ODs that are caused by exposure to agents from work activities. They are the commonest occupational hazard that can result in OD. In addition, chemical agents are also the main contributor to ODs classified by target organ systems especially respiratory and skin diseases as well as occupational cancers.

Toxicology is the study of poisons and how they affect the body. Toxicity is an inherited property of a chemical that causes bodily injury or disease to a living organism as a result of physiochemical interaction with living tissue. All substances including chemicals are potentially poisons. However, all chemicals can be used safely if exposure is kept below tolerable limits. There are various factors that influence the toxicity and the health effects of a chemical agent. These include its physical state, dose or concentration, route of absorption, duration of exposure and presence of other chemicals. Personal factors also determine the effects of a chemical. These include genetic factors, age, gender, health status, hypersensitivity, personal habits and hygiene and pregnancy and lactation.

Chemicals can also be classified on the base of hazards.The Globally Harmonized System (GHS) divides hazardous chemicals in the workplace into different categories; physical hazards,health hazards and environmental hazards (GHS 2007) [2]. Not surprisingly,noise -induced hearing loss (NIH) represents the most frequent occupational disease (25.3%) in the petrochemical industry followed by the musculoskeletal diseases (MSDs) with 22.9% [3]. Malignant tumors of the pleura and peritoneum follow with a proportional rate of 19%, six times higher than that recorded for the total industrial sectors (3.6%). Disease of the respiratory system are clearly proportionally more frequent (16.5%) compared to data reported from the total industrial sectors (6%) [3]. The management of health hazards in the off-shore upstream petroleum industry has its own specific problems [4]. In this mini-review the specific health problems in both sectors will be discussed.

Noise-induced hearing loss (NIHL)

Hearing loss due to noise exposure in the workplace is a significant health problem with economic consequences. NIHL is the OD most frequently reported by the Norwegian Labour Inspection Authority and the Petroleum Safety Authority. Every year the two authorities receive close to 2000 and 600 new reports of NIHL respectively accounting for 60% of all reported work-related diseases in a working-population of 2.7 million [5,6]. Occupational noise exposures causes between 7 and 21% of the hearing loss among workers in general lowest in industrial countries,where the incidence is going down and highest in the developing countries [6]. It is difficult to distinguish between NIHL and age-related hearing loss at an individual level. Most of the hearing loss is age-related.

Men lose hearing more than women do. Heridity also plays a role. Socio-economic position, etnicity and other factors such as smoking, high blood pressure, diabetes, vibration and chemical substances may also affect hearing. Impulse noise seems to be more deleterious than continuous noise. Hearing loss is decreasing in industrialized countries due to preventive measures [6].

Morken et al. [7] examined the incidence of NIHL,among offshore workers on the Norwegian continental shelf reported to the Petroleum Safety Authority (PSA) from 1992-2003. The study revealed a significant increase from 1/1000 employed in 1992 to 9/1000 in 2003. The majority of cases were reported among mechanics, surface treatment workers, electricians, process technicians and rough necks, most of them aged 50-59 years [7]. In 2002, Zachariasen et al. [8] stated that there is a problem with high noise exposure in the Norwegian Offshore. Nistov et al. [9] in a later study reported that there is a high noise exposure level a risk of NIHL and a need for preventive measures in this industry. Ross et al. [10] however found that offshore workers exept for divers had a normal hearing and so did Johnson and Gann in a former study [11]. There is a great deal over the noise exposure and the perceived risk of NIHL in the offshore sector. The number of studies is limited but the evidence suggests that offshore workers as a group have a relaively normal hearing. More and larger longitudinal studies are needed.

In addition to noise workers in the petrocemical industry may be exposed to solvents toxic to the inner ear, cochlear and/or vestibular apparatus, temporarily or permanently. Several studies have demonstrated that chemical compounds like metal fumes (lead, mercury, manganese, cobalt and arsenic) asphyxiant gases (carbon monoxide, nitrate or butyl and tetrachloride or carbon) and organic solvents (toluene, xylene, styrene, n-hexane, tetachloroethylene and disulfide or carbon) may cause hearing loss either alone or when interacting with noise [12,13]. However, data are scarce and current available scientific literature does not establish a causal relationship between the occupational activity in the petrochemical sector and hearing loss [14].

Loukzadeh et al. [15] looked in a cross-sectional study at 99 workers in the petrochemical industry with exposure to a mixture of solvents whose noise exposure was lower than 85dB (decibel) and compared them with 100 unexposed contols. The mean hearing treshold at all frequencies among petrochemical workers was normal (below 25dB). They did not observe any significant association between solvent exposure and high-frequency or low-frequency hearing loss [15]. Exposure standards for chemicals and noise have not yet been altered to take account of increased risk to hearing. Until revised standards are established it is recommended that the 8 hour equivalent continious noise level of workers exposed to the above mentioned solvents should be reduced to 80dB or below accordng to a statement of the Government of Australia, Departments of Mines, Industry Regulation and Safety [16]. Hearing loss due to ototoxic chemicals is mostly sensorineural of origin [14,17].

Musculoskeletal disorders (MSDs)

Since 1992, physicians have reported work-related diseases among workers in Norway's offshore petroleum industry to the PSA, as required by law. Morken et al. [18] analysed the number of reported work-related MSDs and risk factors (occupation and reported exposure) from 1992-2003. During the 12 years 3131 new work-related MSDs were reported and this was the category of work-related disease most frequently reported (47%). The number of work-related MSDs varied substantialy from year to year. Disorders of the upper limb accounted for 53% and back disorders for 20% of all work-related MSDs. Lower limb disorders accounted for 16% of which knee disorders dominated (12% of all cases). The dominant occupational categories were maintenance work (40%) and catering (21%). Frequently reported types of exposure were high physical workload, repetitive work and walking on hard surfaces/climbing stairs and ladders, probably contributing to knee disorders.

Jensen and Hedegaard Laursen performed an epidemiological review study in 2014 of injuries in the oil and gas offshore [19]. Only a few papers were found published between Jan 1 2000 or before and 2013 after an extensive search in PubMed, Cochrane, Embase, Google Scholar and Web of Science data bases. Only 2 studies were found that included incidence rates. The first incidence rate study analysed the fatal injuries in the USA oil and gas production, based on data from 1988-1990 and 2003-2004 [20]. The oil and gas extraction employed approximately 380.000 workers on approximately 1300 drilling rigs in 2006. CDC (Centers for Disease Control and Prevention) analysed the data and found an annual fatality rate of 30.5 per 100.000 workers (404 fatalities during 2003-2006) approximately 7 times higher than the rate for all workers (4.0 per 100.000 workers). Nearly half of the fatalities were attributed to high-way motor vehicle crashes or being struck by machinery or equipment [20].

The CDC previously analysed the 1988-1990 incident reports from the international association of drilling contractors, an industry wide international trade association representing 95% of the world's oil and gas companies. The over-all non-fatal incidence rate was 1.2/100 full-time equivalents and the over-all fatal incidence rate was 7.5/100.000 full-time equivalents [21]. A study of non-fatal injuries from Greece covers 6 years from 1997-2003 of 5000 people from which more than 3000 were employees at the production and storage sites [22]. There were 1024 major injuries during the 6 years and the rough estimate is 57 injuries/100.000 workers. According to work -related MSDs only three studies were found.

Offshore workers from a Chinese oil company were invited to complete a self-administered questionnaire providing information on socio-demographic characteristics,occupational stressors,social support,coping style,health related behaviours,past injuries and musculoskeletal pain [23]. The prevalence of musculoskeletal pain over the previous 12 months varied between 7.5% for elbow pain and 32% for low back pain.At least 56% of the workers had one complaint. Significant associations were found between various psychosocial factors and musculoskeletal pain in different body regions after adjusting for potential confounding factors. Occupational stressors in particular stress from safety, physical environment and ergonomics were important predictors of musculoskeletal pain.

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The prevalence of MSD was assessed in a cross sectional study in 2000 among employees in the UK oil and gas industry predominantly on offshore installations [24]. Assessed by the Nordic Musculoskeletal Questionnaire (n=321), 80% of the sample reported that they had experienced some form of MSD in the past 12 months; 37% reported that they experienced one or more problems over the past seven days. Low back pain was the most frequently reported (51%) and 17% of them in the last week. The prevalence rate of neck, shoulders and upper back MSD was also 17%. Mental health, workload, physical environment stressors and body mass index predicted MSD with a different relative importance across different body areas.

A Norwegian review of epidemiological studies on health conditions among offshore petroleum workers include a few publications but none with data illustrating incidences or prevalence rates after 2000 [24-27]. The authors expressed a doubt whether the prevalence of MSD differs from that among onshore workers. They propose that the main risk factors are physical stressors and a fast pace of work.

The work-related diseases from Norway's offshore petroleum industry notified by the physicians to the PSA were analysed [28]. For the period from 1992-2003 there were 6725 cases of work-related diseases out of which 3131 were MSDs (47%). The other large groups were hearing loss (25%) and skin diseases (15%). Among the MSDs upper limb disorders accounted for 53%, back disorders for 20% and lower limb disorders for 16% of which knee disorders dominated (12% of all cases). The authors of the Norwegian review of MSDs expressed doubt like the British study authors whether the prevalence of MSDs differs from that of onshore workers [24,28].

Cancers

Offshore production of crude oil and natural gas developed in the North Sea from the late1960's onwards. In Norway, cancer incidence has been reported from 2 cohorts of offshore workers both of about 28.000 workers. Stenehjem et al. [29] merged these 2 cohorts to one in order to update the analysis of cancer incidence in a largerand more complete sample of Norwegian offshore workers with a follow up extended to 2009. In this large group of offshore workers they found an overall cancer incidence in line with expected numbers for men and a slightly elevated incidence (17% in excess of expected) for women. There was an excess risk of pleural cancer in male workers and an excess of AML (acute myeloid leukemia) in women which was a novel finding. There was no sign of any overall excess of lymphohaematopietic cancers in men. There was a doubled risk of malignant melanoma and a 69% increase of lung cancer in women, while in male workers a 25% increase of bladder cancer was observed [29]. Lack of information on exposure work history and life style factors hampers the identification of possible causal factors.

All 21 pleural cancers were mesotheliomas and asbestos exposure the most likely explanation may have taken place when asbestos was used offshore as a drilling mud additive (until 1980) and in derrick brake bands (until 1991). However a similar increased risk was found in workers employed after 1985, suggesting that exposure outside the offshore may have played a part at least for the seven cases in the latter group. Excess mortality and incidence from pleural cancer have been reported in UK and Australian petroleum workers, both ascribed largely to asbestos exposure in oil refineries [30,31]. In women a significant increased risk of AML was found but based on 5 cases only. Further clarification of the possible role of offshore work in cancer etiology requires information on exposure and potential confounders [29].

However, Stanehjem et al. [32] found an increased risk for AML, MM (multiple myeloma) and suggestively for CLL (chronic lymphocytic leukemia) between cumulative and intensity metrics of low level benzene exposure in a cohort subanalysis of 25.000 Norwegian men working offshore beween 1965 and 1999. These findings are generally in line with other studies conducted in petroleum workers. Kirkeleit et al. [33] reported a three-fold increased risk of AML in Norwegian upstream operators employed before 1985. An Australian study reported a seven-fold increased risk of CML among petroleum workers exposed to >8p.p.m./years [34]. Further, a study in UK petroleum marketing and distribution workers reported increased risks of AML or monocytic leukemia in relation to cumulative, duration and intensity metrics of benzene [35].

A pooled analysis of Canadian, Australian and UK data, comprising a total of 60 AML cases showed an elevated risk of AML according to cumulative, intensitivity, duration and peak metrics of benzene exposure [36,37]. A study of leukemia risk in relation to gasoline Spill in Pennsylvania, USA, suggested a dose-response relationship between atmospheric benzene levels <1p.p.m. and AML [38]. Moreover, recent studies have detected genotoxic effects and altered gene expression linked to leukemia among workers exposed to low levels of benzene (i.e. <1p.p.m.), which supports a biological plausability for a dose-response relation between average benzene levels [39-41]. Although benzene exposure during ordinary and high activity seems to be low in the processing area on a production vessel, cleaning of tanks and performing maintainance work in a cleaned tank have a potential for high exposure [42]. Other studies also observed an elevated risk of CLL in relation to benzene exposure [34,35,43].

There is an increased risk of multiple myeloma for all exposure metrics with a statistically trend test for cumulative exposure [32]. These findings are in accordance with those published by Kirkeleit et al. [33] of increased risk of MM in upstream operators employed offshore before 1985 and with similar findings of two meta-analyses [33,44,45]. In their most recent evaluation of benzene as a carcinogen the IARC (International Agency for Research on Cancer, WHO, Lyon, France) pointed out that NHL (Non-Hodgkin Lymfoma) is a heterogenous group of histological subtypes and that a few cohort studies have reported benzene-related risks of NHL [46]. Measurements of benzene exposure are mainly conducted since the year 2000 [47,48].

Dermatitis

Skin contact with drilling fluids or mud can cause inflammation of the skin referred to as dermatitis. Signs and symptoms of dermatitis include itching, redness, swelling, blisters, scaling and

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other changes in the normal condition of the skin. On the drill floor, in particular skin contamination can be broad, but occasionally dermatitis also occurs in divers who make contact with discarded cuttings on the sea bed [49]. Petroleum hydrocarbons will remove natural fat from the skin which results in drying and cracking. These conditions allow compounds to permeate through the skin leading to skin irritation and dermatitis. Some individual may be especially susceptible to these effects. Skin irritation can be petroleum hydrocarbons, specifcally with aromatics and C8-C14 paraffins. Petroleum streams containing these compounds such as kerosene and diesel (gas oil) are clearly irritating to the skin. This is suggested to become malignant caused by the paraffins which do not readily penetrate the skin but are absorbed in the skin hereby causing irritation [50]. Linear alpha olefins and esters commonly used in drilling fliuds are only slightly irritating to the skin whereas linear internal olefins are not irritating to the skin.

In addition to the irritancy of the drilling fluid hydrocarbon constituents several drilling fluid additives may have irritants, corrosive or sensitizing properties [51]. For example, calcium chloride has irritant properties and zinc bromide is corrosive whereas a polyamine emulsifier has been associated with sensitizing properties. Although water based fluids are not based on hydrocarbons, the additive in the fluid may still cause irritation or dermatitis. Excessive exposure under conditions of poor personal hygiene may lead to oil acne and folliculitis [52]. ASTDR concluded that it is reasonable to expect that adverse haematlogical and immunological effects might occur following dermal exposure to benzene [53]. The use of PPE (personal protection equipment) and barrier creams might reduce the incidence of contact dermatitis. However, the use of barrier creams requires careful monitoring since in some cases, they were regarded as a form of PPE [28].

Inhalation risks

Although base-oils have attracted the most attention, workers are potentially exposed to a range of particulates esecially during powder handling in the sack room (various additives, especially barium sulphate) and at the shale shaker (aerosols from mud and the strata being drilled). With respect to the sack room few exposure data have been published. Hansen et al. [54] published detailed elemental analysis of airborne dust from 16 static samples from a shale shaker room during drilling using a water based mud. Total airborne dust concentrations at the working area were in the range of 0.05-0.7mg/cubic meter. Barium sulphate was the major component of the mud and not surprisingly the element found in the highest concentration was barium. The concentrations were equivalent to 0.4-0.5mg/cubic meter. Current accepted levels for respirable and total inhalable dust are 4 and 10mg/cubic meter respectively [54]. Studies about the prevalence and incidence of COPD (chronic obstructive pulmonary disease in offshore petroleum workers and workers in the petrochemical sector are not available.

Conclusion

Half a century of occupational medicine in the offshore petroleum industry and the petrochemical sector yielded a disappointing number of scientific publications. With thanks to the Norwegian government instituting a compulsory reporting requirement by law in 1992 some valuable publications are available. A picture is rising of hearing noise, musculoskelatal disorders, dermatitis and debated cancers as the main ODs in these sectors. Attention for job stress and mental health, addictions and COPD have been minimal. Information about exposures at work places, working history and life styles to establish causal relationships is missing. Part of the problem is the historical bad communication between occupational physicians and the curative sector and vice versa, in providing each other information [55]. The inflow of occupational physicians and the esteem is low. Nevertheless, people spend a great deal of their lives at working places and deserve more and better occupational medicine. After half a century more questions are open than being answered.

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From Awareness to Action: The Community of Sarnia Mobilizes to Protect its Workers from Occupational Disease

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Abstract

An exploratory qualitative case study investigated how different sectors of a highly industrialized community mobilized in the 1990s to help workers exposed to asbestos. For this study, thirty key informants including representatives from industry, workers, the community, and local politicians participated in semi-structured interviews and focus groups. The analysis was framed by a "Dimensions of Community Change" model. The informants highlighted the importance of raising awareness, and the need for leadership, social and organizational networks, acquiring skills and resources, individual and community power, holding shared values and beliefs, and perseverance. We found that improvements in occupational health and safety came from persistently communicating a clearly defined issue ("asbestos exposure causes cancer") and having an engaged community that collaborated with union leadership. Notable successes included stronger occupational health services, a support group for workers and widows, the fast-tracking of compensation for workers exposed to asbestos, and a reduction in hazardous emissions.

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knowledge transfer, occupational cancer, community-based research, knowledge to action

Introduction

More than 30% of cancer deaths, according to the World Health Organization,[1] could be prevented by modifying or avoiding key personal risk factors. A report from the Canadian Cancer Society and Cancer Care Ontario states that over 50% of cancers that will be diagnosed over the next twenty years, caused by individual lifestyle factors and occupational and environmental exposures, could be either prevented or detected early before they become a serious health problem.[2] This study focuses on the occupational exposures that are preventable. Since it is estimated that 8.0% to 19.2% of just lung cancer in American men can be directly attributed to workers being exposed to occupational hazards,[3] it is important to reduce the exposure of vulnerable workers to workplace carcinogens such as asbestos, nickel, silica, diesel, benzene, and many other substances.[4–6] However, raising public awareness of the carcinogenicity of occupational hazards is not easy, and more importantly, even when there is awareness of exposures, there is still the question of how to raise awareness of the impact on worker health and encourage the prevention or reduction of exposures to workplace hazards.

This gap between awareness and taking action has been investigated by numerous fields of inquiry, including public health, psychology, sociology, and in particular, the field of knowledge transfer (KT). Awareness seems to be necessary for change, but it is not always sufficient to lead to action. For example, society has known with reasonable certainty for many decades, maybe for more than a century, that asbestos can cause cancer,[7] and asbestos exposure is the single largest on-the-job killer in Canada, accounting for more than a third of total workplace death claims approved last year and nearly a third since 1996.[8] Despite this awareness, change has been very slow, socially, economically, and legally. The last asbestos mine in Canada closed as recently as 2011, and shockingly, according to Statistics Canada figures, imports of asbestos-related items rose to C$6-million last year from C$4.9-million in 2013 and exports continue.[9]

The objective of this exploratory study was to try to understand what helps to bridge the gap between awareness of occupational exposures and taking action to reduce exposure and protecting workers who have been exposed. This question is fundamental to the field of KT. The study of KT (commonly known in the United States as dissemination and implementation science) focuses on the transfer and adoption of evidence-based knowledge and the subsequent behavioral change (usually at a community, organizational, or social level).

In this study, we asked how a community progressed from the awareness of the health impact of asbestos to taking action to achieve support and compensation for workers who had become ill from workplace exposures. We explored the fulcrums-of-change that helped to bridge this gap from multiple perspectives: workers, industry, community, and local politicians. We attempted to identify the pivotal facilitators and barriers that the community encountered. We also explored whether this awareness about asbestos has continued or transferred to other chemical industry-related hazards in the workplaces and the community.

The City of Sarnia was chosen for this study. It is a small (population 72,000), relatively isolated, racially homogeneous city in Ontario, Canada, that is dominated by the petrochemical industry. It is located where Lake Huron flows into the St Clair River at the Canada–United States border, directly across from Port Huron, MI. It is a predominantly white community (where people speak either English or French as their first language).[10] In 2011, only 3.6% of its population identified themselves as a visible minority[11] as compared to 25.9% of Ontarians in general.[12] The city is bordered by the Aamjiwnaang First Nations Reserve to the south.[13]

The city hosts nearly 40% of Canada's chemical industry with sixty-two industrial facilities along its border region.[14] These refinery and chemical plants are found in a 25 km radius of the city in what is known as Chemical Valley. At its peak in the 1970s, Sarnia had the highest standard of living in the country, with a per capita disposable income 35% greater than the national average.[15] For several years, an iconic image of the city's petrochemical industry graced the back of the Canadian ten-dollar bill.

Sarnia has high rates of particulate air pollution and higher rates of cancers when compared to other cities.[16] For example, a report using 2005 data, noted that 5.7 million kg[16] of air pollutants were emitted from the region resulting in several Ministry of Environment Orders.[17] Using 2011 data, the community ranked first, fourth, and eighth in emissions of tetrachloroethylene, chloroform, and nickel, respectively, of 159 Canadian cities.[13,14,15] According to a 2011 report by the World Health Organization, Sarnia was rated as having the worst air quality in Canada.[14,18] Recently supplied 2008–2010 data from Cancer Care Ontario says cancer in Sarnia-Lambton (a merged municipality) is more prevalent than elsewhere in the province, with a local cancer rate of about 433 cases per 100,000 people. This being noted, recent regional advances in air quality have been observed.[19,20] Over the last ten years, nitrogen dioxide and sulfur dioxide emissions have dropped 50% largely due to community concerns and efforts in conjunction with local industry.[19]

We chose Sarnia for this study because of its presumed high rates of awareness—a scan of the city's important newspaper articles since 1952 revealed significant growing media coverage about the health effects of exposure to asbestos. This awareness reached its peak in the late 1990s when the community became aware of an increasing number of workers becoming ill and dying from lung cancer and mesothelioma (and other cancers and medical heart issues). Mesothelioma, in particular, is a rare cancer that is directly caused by asbestos. Workers raised the alarm. It emerged that the sick and dying workers came predominantly from two companies, the Holmes Foundry and Fiberglas Canada. These were notoriously dirty and dangerous plants where exposure to multiple hazards, including asbestos, was very high. The unions and community activists collaborated to raise awareness of the hazards of occupational toxins and hazards, but the focus quickly became just asbestos. The first community meeting was held in 1996. The unions held clinics for workers from these two workplaces to map their exposures, created a support group for workers and their widows called the Victims of Chemical Valley (VOCV), and lobbied government. A temporary occupational clinic was set up to handle the increasing load of compensation cases, and the head of the clinic together with union leaders rallied the community and increased media awareness. The combined union and community action led to the support and fast-tracking of compensation for exposed workers, the permanent status of the occupational clinic in Sarnia, the building of a hospice, and much closer monitoring of occupational and environmental exposures by industry. This effort to raise awareness and to achieve change for workers has been written up in other contexts (See Table 1).[21–23]

Table 1. A timeline of community awareness and action: the history of Sarnia's demand for recognition of the impact on workers' health from exposure to asbestos.

Workers raised awareness	• A worker at Fiberglas Canada (owned by Owens Corning) tracked obituaries and with help of the Occupational Health Clinic for Ontario Workers (OHCOW) raised the alarm; • Over 1000 claims were filed to the Workers' Compensation Board (WSIB), many for cancer; • Since the Holmes Foundry (closed in 1980) and Owens Corning Fiberglas (filed for bankruptcy in 2000) were already closed, the workers were the ones who held the institutional memory of these two companies.
Community involvement	• A community organization took a very strong leadership and advocacy role. • A researcher became the Executive Director of OHCOW and conducted an analysis of the cluster of cancer and deaths; • With the help of the union, the widows and victims came together to form a group; • The demand for recognition of occupational disease sets up a divide in the community, with many workers regarding exposures as part of the job, concerned about their pensions, and grateful to the companies for their well-paying work; • The widows joined the union in a sit-in at the Ontario legislature and negotiated the temporary funding of OHCOW in Sarnia.

(continued)

Table 1. Continued.

Union involvement	• The unions got involved and took a very strong leadership role. • In 1998, the Health and Safety Co-Chair of the CEP local union Local 914, who was Chairperson for the Labour Council organized two intake clinics for workers who worked at Fiberglas Canada (represented by CEP) and Holmes Foundry (represented by CAW); • He helped to find an organization of widows, the Victims of Chemical Valley; • The Ontario Federation of Labour (OFL) organized a cross-Canada tour to raise awareness of occupational disease with the victims group; • The OFL and the Victims group raised awareness of their plight in the Ontario legislature; • In 1999, the OFL held a conference on occupational disease and 1000 members attended; • The OFL created a one-day workshop on occupational disease that was widely taught to workers and activists; • The Victims organization (VOCV) was recognized in the Ontario legislature; • The Sarnia occupational health clinic (OHCOW) received temporary funding.
Media attention	• From 1998 to 2000, at least thirty major articles (front page) and editorials were written about asbestos and cancer in Sarnia; • An annual march was organized by the VOCV and the Union to raise awareness.
Political action	• Local politicians discuss the health impact of asbestos (occupational exposures and cancer was mentioned in the Sarnia municipal council); • In 1999, a private member's bill on allowing benefits for side-exposure victims (wives of workers), (Lynne Henderson Bill) achieved second reading; • The Ministry of Labour (MOL's) department of hygienists and other clinical practitioners was not shut-down, despite widespread cutbacks led by the government of the day. This is considered significant; • The MOL lowers some occupational exposure limits for particularly toxic substances; • The MOL makes the occupational clinic in Sarnia permanent in 2004. This is a big achievement, but the MOL emphasizes that it will not fund prevention activities or activism at the occupational clinic. This significantly reduces community leadership on the issue of occupational exposures.

(continued)

Table 1. Continued.

Industry reaction	• Industry dominates as the major employer in a relatively homogeneous community. • Industrialization, globalization, and automation led to severe cutbacks of the workforce. Major plants were closed in 2003 and onwards. By default, fewer workers are exposed to chemicals; • Industry outsourced much of the most toxic work to non-unionized contractors; • The Sarnia-Lambton Environmental Association, with representation from twenty companies, monitors the companies' environmental emissions. The Sarnia-Lambton Industrial Educational Co-operative establishes common OHS education for workers in the petrochemical industry; • The industry has helped fund a health study (2014) that will examine the health effects of environmental emissions; • Established a relationship with the First Nations communities that border on some of their properties; • New companies are now built away from the Sarnia river and industrial outputs are monitored more closely.
Community achievements	• Compensation claims are now processed with greater understanding by WSIB; • A hospice was established; • The community built a memorial to the victims of chemical valley; • A clinic for occupational health (OHCOW) achieved permanent funding; • The "toxic blob" in the Sarnia river was cleaned and is slowly dissipating.
Unintended outcomes	• In their opinion, with layoffs, cutbacks, and closures, the unions have lost a significant amount of their power base and their ability to demand change. They now focus on survival, retention of jobs, and saving pensions, and do not have the time or resources to launch another campaign on occupational disease; • Community leadership has dissipated; • OHCOW lost its ability to do prevention work and ceased to be a major community hub for activism

Note. OHCOW = Occupational Health Clinic for Ontario Workers; WSIB = Workers' Compensation Board; CEP = Communications, Energy and Paperworkers Union of Canada; CAW = Canadian Auto Workers; OFL = The Ontario Federation of Labour; VOVC = victims organization; MOL = Ministry of Labour.

Conceptual Framework

This case study is a historical account, as remembered by key informants, of how the increasing community and worker awareness of the health effects of occupational exposures, especially the growing knowledge of how asbestos caused mesothelioma and lung cancer, led to community and union action. It examined the roles and interactions of the different players in these efforts to prevent this hazardous exposure and the actions that led to support for sick workers and their families and explored whether and how companies changed their processes to reduce workers' exposure to asbestos.

The study was informed by an adapted version (with permission from Minkler et al.) of a conceptual model that comes from the field of community development[24–26] and the "Dynamic Model of the Dimensions of Community/Partnership Capacity, their Contextual Factors, and Potential Outcomes (See Figure 1)."

The conceptual model was selected for this study because it includes a number of dimensions of community change and also takes into account the external climate.[24] It has been used to identify the pivotal variables for racial and ethnic communities taking on community initiatives such as reducing diesel emissions

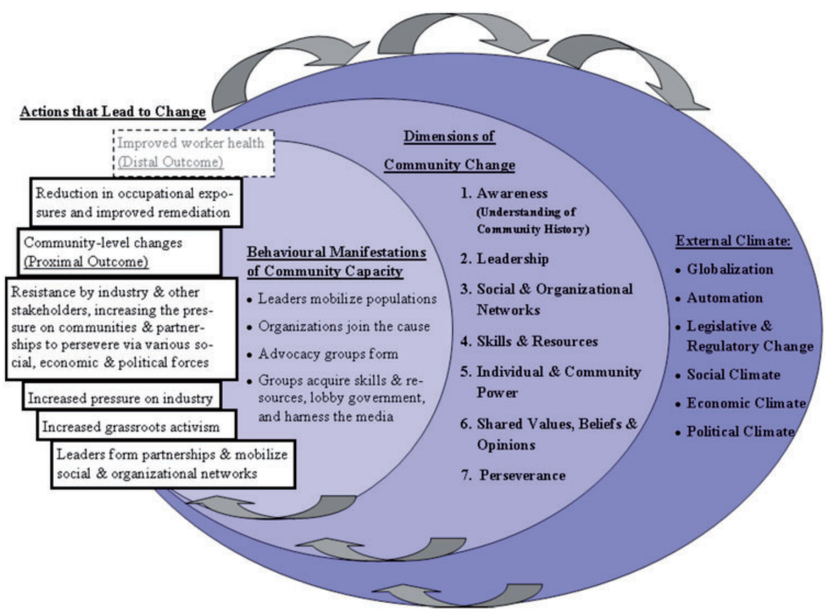

Figure 1. "Dimensions of community change" model. Adapted from Minkler et al.,[24] Goodman et al.,[25] and Freudenberg.[26]

from idling buses in Harlem, stopping the use of mine tailings in construction unless contained, getting routine lead testing for at-risk children in Ottawa, and getting a moratorium on industrial hog operations in Halifax.[25,27]

The "Dimensions of Community Change" model helped frame the questions that the researchers asked of the thirty participants, their team discussions, and their analysis of the interviews. The model evolved as a result of emerging knowledge gained during this study. The community change level of the model originally had ten dimensions; they were condensed to seven. They were rearranged in order of importance, and some were altered to a similar, but more applicable concept. The seven are Awareness; Leadership; Social and organizational networks; Skills and resources; Individual and community power; Shared values, beliefs, and opinions; and Perseverance. Although the model includes the external climate as an essential part of the change process, so few respondents responded to questions on social, economic, political, and global pressures, that these have been excluded from the following analysis.

Research Methodology and Procedures

The study received ethical approval from the Community Research Ethics Office, based in Kitchener, Ontario. Seven site visits were made to the city over a period of two months to conduct interviews and focus groups. The research team recruited a convenience sample of participants based upon their existing network. Since many of the interventions that can reduce workers' exposure are dependent on workplace parties, the recruitment process emphasized industry management and union representation. Interviews were conducted with labor,[7] community members,[9] local politicians,[6] and industry representatives[8] to capture various perspectives. The seven interviewees in the labor category included mostly people who had been at the time of interest (early 1990s) union representatives or were members of organizations sponsored by the unions. Half of this group had worked in the petrochemical industry, including a member of the Aamjiwnaang First Nations Reserve.

The six local politicians were local municipal representatives, leaders from the local community college, and members of the Better Business Bureau. The eight industry interviewees were members of the Sarnia-Lambton Environmental Association (SLEA). SLEA is made up of representatives from twenty of the sixty-two petrochemical companies in Chemical Valley, some of the largest in the area. The organization is nearly fifty years old, and its objective is to monitor and report industrial emissions. The members are plant managers, senior production managers, and health and safety directors. In the past, they have had a difficult relationship with the community and with the Aamjiwnaang First Nations Reserve due to the perception of underreporting.

The nine community members included a mixed group of activists who were associated with the VOCV, the Sarnia-Lambton Community Health Study, and three representatives from the First Nation community. The VOCV was one of the first initiatives of the unions and is made up primarily of widows. This group of mainly women ended up carrying the moral authority of the action, although most of the key actors were male workers, union representatives, and management. The Sarnia-Lambton Health Study was initially formed in 2008. It has representatives from municipalities, First Nations, business, labor, industry, occupational health, victims of occupational illness, and public health. It recently received a commitment from SLEA that the companies will fund 30% of an environmental health impact study (a percentage that was negotiated to ensure the impartiality of the study and its results). The remaining money to cover the cost of the study is still to be obtained.

In total, four First Nation community members were interviewed. As mentioned, one was included in the labor group since he had worked in the petrochemical industry for decades, and the other three were included within the community group to protect their anonymity. There would have been many advantages to having the voices of more members of the Aamjiwnaang First Nations Reserve represented. The research group is under discussions to make that a focus of future research noting the research protocol guidelines as outlined by Canada's Assembly of First Nations.[28]

Since Sarnia is such a tight-knit community where individuals often span multiple categories, some participants spoke from multiple perspectives. The researchers emphasized to the interviewees that all data would be aggregated, and no identifying information would be used to ensure their anonymity and confidentiality and that of their companies.

Semi-focused interview schedules were created based upon the conceptual framework. Four slightly different schedules were created depending upon which group the interviewee fit. They were modified during the study reflecting evolving knowledge. With the exception of two people (one industry and one politician), all requests for interviews were accepted. Four of the participants were interviewed more than once. Each semi-structured interview lasted about an hour; to achieve consistency, all the interviews were conducted by the lead researcher.

Special attention was paid to the person's awareness of occupational exposures and whether that individual thought such exposures were an issue in the community; what changes the interviewee had seen over the last ten to fifteen years, and what role he or she had played in that change; what actions they thought the community or unions had taken to support the reduction in occupational exposures; what changes the companies had made; whether industry management treated critical safety issues differently from workplace exposures with long latencies; what resources were needed to make change at the community level (leadership, skills, expertise, time, perseverance); and what, if any, external environmental factors impacted their stories.

Two focus groups were also facilitated. One with community activists and another with a group made up of management representatives from different petrochemical companies. Other supportive data were collected such as information on websites, annual reports, emission reports, and historical reviews that were available at the time. The data helped inform or contextualize the findings. The researchers also asked the companies for access to any exposure data they were comfortable sharing that demonstrated improvement over time. Although one data set was offered, permission to use it in the study was not granted for reasons of company confidentiality. Newspaper headlines about important historical events in the city were turned into posters and used in the focus groups to encourage memory and reduce recall bias.

The interviews and focus groups were digitally recorded and transcribed by a research-team member. The team met often to discuss the findings relative to the conceptual framework. Discussions focused on where the findings converged and diverged from the framework and on emerging themes.

Data Analysis

Interviews were conducted until saturation of themes was reached, and the research team achieved an in-depth knowledge of the community and multiple perceptions on what influenced the awareness-to-action process. The qualitative analysis was guided by the conceptual framework. However, as mentioned, the interviews only had rich data on the inner circle of the framework, the Dimensions of Community Change, and hence this is where the analysis has focused.

Matrices were developed; one axis had the seven key components of community change and the other axis divided the interview data into the four informant groups. The matrices helped to organize, summarize, and code the text in a continuous iterative process, which facilitated a comparison between the four groups, allowed for dominant themes to emerge, and helped the research team draw conclusions from the data.

Coding for the interviews was done by one member of the research team and then discussed with two other members to ensure agreement on categories and themes. All data were aggregated and anonymized to protect the privacy of individuals and companies.

This study reports on its results in two ways in order to gain as much understanding as possible of the research question: How did this community go from awareness to taking action on occupational exposures?

The first part of the analysis focuses on how the four groups (workers, industry, community, and local politicians) responded to the dimensions of community change: Awareness; Leadership; Social & Organizational Networks; Skills & Resources; Individual and Community Power; Shared Values, Beliefs & Opinions; and Perseverance. This section has been called the Dimensions of Community Change. The narratives from the four groups mapped well onto these dimensions (See Table 2).

Table 2. Matrix of illustrative quotes from the four community groups.

	Labor	Community	Local politicians	Industry
Awareness (Understanding of Community History)	For many, many years workers have known there's a risk in the plant, of course. And even the owners and people who run the plants often said this is the smell of money and this isn't a candy factory that you're working in here, so get at it.	I think the community is fairly aware of it. Enough people work in industry, even with their family members being there, I think they have a sense of . . . the importance of occupational health.	It's not that it's not on our radar. I think we think of it . . . as a legacy issue.	Ok, by simply living here in Sarnia, you are very conscious of what has happened in the past, of the different factories, foundries and so forth, and even the Valley, how they dealt with certain substances, certain chemicals.
Leadership	[The occupational health leader was incredibly important]. Maybe the key glue, the key player. Because he would . . . give me perspective on the situation I was in. He was the person who first recognized how many workers were being impacted and could portray it in a salable fashion.	The unions, they're the one that can drive change.	Because of the process and the way that it is, the problem is that [municipal governments] usually aren't involved until something has gone wrong and we're usually the ones saying to the province, "hey we've got a problem over here."	So I think [SLEA (the industry organization)] has . . . been a leader in our community and . . . a leader around the globe, because that was industry coming together to look at what some of the spills were, what some of the incidents were . . .. It was industry coming together to look and learn from each other.

(continued)

Table 2. Continued.

	Labor	Community	Local politicians	Industry
Social and organizational networks	VOCV [the Victims of Chemical Valley] kept the pressure up here in Sarnia, and [the union] went to city hall and the city council, and asked them to pass a resolution banning asbestos in Canada and they did.	We at Council meet with industry. When we meet with Suncor, we meet with Shell. And they have to advise us on anything that's going on, like the shutdowns. There might be a flare up, there might be heavy traffic. They have to make us aware of that. It's just our agreements with industry, because it does affect us.	There's a distancing, the industry feels, I think, isolated from city council and so it's hard.	We were in a mode, and I think others in the Valley were in it a little bit too, of only talking to each other when we had to, when the MOE [Ministry of Environment] made us, and just not recognizing the importance of having a more open dialogue and knowledge of who each other is and respect for each other.
Skills and resources	[During] my first meeting . . . I didn't really say a whole bunch, but when I got out of there I said, 'you know what? I'm going to be able to talk to that guy in a few months. I'm going to understand what he's telling me and when I start answering him, he's going to be taken aback because somebody's actually talking back to him.	I have to go to all these meetings to hear and learn [about what's going on] because you are not taught [any] of this in school around here at all.	I think lots of times there's very passionate people. Quite often they're small in numbers. They go as far as they can. Legal challenges start to happen. Money is hard to find. Big companies have all kinds of money. So eventually these very passionate people run out of resources.	[We will make changes] if we're causing health impacts, but right now we don't know because we don't have any data that says we do. We're not trying to hide from data that might say we do. But if we can study it and understand it better, then we know what we need to do.

(continued)

Table 2. Continued.

	Labor	Community	Local politicians	Industry
Individual and community power	What changed was that the workers' voice had credibility. When people said that these conditions were bad, or that we have an asbestos problem or we're getting exposed to benzene, the workers were believed.	The companies had developed tremendous paternalism . . . where they had complete control over the media, the social fabric, the middle class, the medical community, and it goes on. So there was a tremendous dominance of the industry in the community.	What we do have is the fact that [the companies are] in the community, and [I ask them], do they want to have a good relationship and a good image in the community?	Since inception, for 2,606 days, we've never had a recordable injury. First aid and a little band aid, fine, but never anything [serious]. No lost time injury ever, whatsoever.
Values	There's something wrong when a person commits [his] life to an employer and [his] reward for it is to lose the last part of [his] life. There's something inherently unjust about that and it struck my sense of values very strongly.	And I said, well, we have an ethical obligation. This is nothing to do with the companies. This is protecting the lives of people in this community. That's where our loyalties should be.	You need the companies to be here, you need the jobs, but if it's a total disaster, no, I don't want the companies here. If there's something going on and it's proven to be that bad, and people are suffering and people are dying, well to me that's a no brainer. I don't want to see folks lose their lives; I don't want to see children lose their parents. For me that's a no brainer.	You can't remain competitive [in the world] unless you're always looking for ways to improve; whether that's your bottom line, your processes, your health and safety performance, [or] your environmental performance.

(continued)

Table 2. Continued.

	Labor	Community	Local politicians	Industry
Cognitive dissonance	The workers' behavior is, 'I'm willing to take the risk or . . . be silent in order to make $100,000 a year and provide for my family . . .. [In] some other town I would not be able to do that with the education I have.'	People didn't have much option. They were good paying jobs. People had come back from the war and you knew that these jobs were hazardous, but you accepted that. People would say if you complained about it, people who had been there during the war or in the army said, 'You think this is dangerous, you should have seen what I went through.'	But even when it was a blue collar town, it was a blue collar town where people had really nice homes and usually a cottage and a boat. They were well-paid.	It's the same answer to the question: 'Are you willing not to drive your vehicle so that we can improve the environment.' 'No. I'm not.' Ok. Are we willing to take 3 years of no returns, not because of the market, but because we're telling the stock market [that we are going] to invest in the health and safety of the plants that they're investing in. No, we're not.

(continued)

Table 2. Continued.

	Labor	Community	Local politicians	Industry
Perseverance	Oh dear. Wow. I'm tired . . .. I've been tired [for months]. I'm not only tired [of] thinking about [doing advocacy], but doing this [advocacy]. It gets harder and harder. To re-engage, to truly re-engage, . . . would be a big effort.	What am I supposed to do? Wait till it does happen to me? No, I'm not. So that's why I say I'll go down with a fight. You can't stop me. I'll just keep talking.	Because you care about people. You care about the community you live in. That's why you do what you do. And you're only one voice. So you do what you can.	When something does go wrong . . . you get renewed attention and there might be more investment if there are gaps found. That's the tricky bit.. . . You can go through long periods of time where you're very successful in preventing accidents [and] incidents from occurring, and then something happens - despite all best efforts.

The second part of the analysis focuses on the four groups—industry, workers, community, and local politicians—and their perspectives on whether awareness had been necessary to reduce workers' exposures to hazards in the workplace, what changes had taken place to reduce these exposures, whether the workplace was a better place now in comparison to the past, and if there was an improvement, what did the interviewees see as the fulcrums of change that had achieved this change. This section has been called the Fulcrums of Change.

Dimensions of Community Change

Awareness

This study was predicated on the assumption that there has existed a high level of awareness of the negative health effects of occupational exposures in Sarnia since the late 1990s. Even before there was public awareness, workers said that they were always aware they were working in an environment that could damage their health.

In the late 1990s, the media, including the *Globe and Mail*, Canada's national newspaper, began reporting on the illnesses and tragic deaths of workers, and public awareness of occupational exposures came into focus. The media coverage was facilitated by the analysis of the problem by an academic occupational health leader. A number of respondents noted that he reviewed Sarnia's elevated levels of mesothelioma, and by virtue of his research, his personality, and the support he had from the unions and community activists, he raised the city's awareness to the dangers. The concept of the "credibility of the messenger" is a very important one in the field of KT.[29]

As other union and community advocates joined the effort, the unions (the Communications, Energy and Paperworkers Union of Canada, the Ontario Federation of Labour, and the Canadian Autoworkers) held multiple intake clinics for exposed workers at two plants: the Holmes Foundry and Fiberglas Canada (and later, others). These clinics helped workers organize the necessary paperwork to submit compensation claims. At this point, public awareness increased through discussions and shared stories. One worker who became a union representative noted this incremental growth in awareness:

> As the years went by, and you start to see people getting ill, then of course the awareness of the hazards became embedded pretty solidly in people who work in the industry. When you start to see people who you were on the same shift with, developing disease, exposure-related disease, then yeah. Then you get it.

Other ways that people became aware included the sickness or death of a loved one, involvement with unions, legislation, labeling on hazardous materials, learning from family members in industry, exposure to the health care sector, and industry outreach.

However, the level of awareness and hence potential demand for improvements in the work environment was also suppressed due to the inherent conflict between the benefit of having a well-paying job and the risk of becoming ill after a long latency period. A dirty and dangerous environment was considered inherent by many workers to their work, and there has always been a culture of gratitude toward the companies that have provided well-paying jobs and an acceptance that risk to one's health is part of the job. Advocates recalled how difficult it was to raise awareness because criticizing the companies was not acceptable: "This was never discussed. It was not public knowledge", said one worker. This emerged as a dominant theme.

Another identified issue, which was validated by almost every respondent, was that the publicity focused in on the health impact of only asbestos, and not necessarily on occupational carcinogens in general.

A unionist said:

> Asbestos is bad for you, we know that. People in this community, most of us, we know that. Whether you're a white collar worker or a blue collar worker, a member of a family of somebody who works in the trades or in the Chemical Valley, you know that asbestos is bad for you

The level of awareness and activism has declined since the 1990s, and the reason given is that the environment and workplaces in Sarnia have improved significantly in the last couple of decades. Many of the interviewees from each of the groups stated that occupational exposures (mostly referring to asbestos) were no longer an issue today. They considered such exposures to be a "legacy issue" and not a current problem. They talked with emphasis about how things have improved since "the bad old days." This view was not universal. An opposing voice came from the widows of the VOCV who continue to try to maintain the community's awareness of the health impacts of asbestos and to advocate for a ban on asbestos, and some industry workers who acknowledged that although there have been substantial improvements, they are aware of carcinogens and potential exposures that still exist in the plants.

Despite occupational exposures losing their spotlight, there is currently much public interest in an emerging community health study. It is predicted that the study will take three to four years and cost $4.8 million, and it will attempt to assess the community's health in response to concerns regarding environmental emissions. The study is receiving a third of its funding from the SLEA,[30] contingent upon the study also receiving government financial support.

Leadership

Depending on their perspective, all four groups considered the role of leadership as essential, although they identified leadership differently. Advocacy efforts were multipronged and required different people with different expertise, skills, and networks. Labor and community members spoke about the importance of leadership as a resource when trying to raise awareness about occupational exposures. They identified union activists as leaders who organized the intake clinics, supported the occupational clinic, formed the victims' advocacy group—the VOCV, took the widows to Toronto to lobby the provincial government, and helped sick workers and widows file for compensation.

The community said their leadership came from a diverse group of individuals, which included the occupational health clinic leader, union leaders, the VOCV, health-care workers, and certain senior local politicians. Many identified the occupational health clinic leader as "the key glue, the key player" in their attempt to raise awareness of occupational exposures.

As mentioned, the industry members were mostly plant managers and senior production engineers who spoke from the perspective of their companies. They spoke about the improvements they had made since the 1990s. They focused on the ways in which their companies were leaders compared to other chemical companies. They were proud of their low injury rates, their improving connections with the neighboring Aamjiwnaang First Nations Reserve and the Sarnia community, and their environmental performance. They noted that recent changes were a significant improvement from what had existed previously, and that these workplace and community initiatives were important to them. Their activities were supported by their head offices, but they took personal credit for the changes since they had led the initiatives. (It is worth noting that it was not possible to validate the stated positive relationship between industry and the local First Nations since the number of First Nation interviews was too small.)

A number of the chemical companies have taken leadership as a group by forming the Sarnia Lambton Environmental Association (as mentioned, SLEA mostly monitors and reports on ambient air quality), the Industrial Education Cooperative (which works with the construction companies and unions to standardize occupational health and safety training for construction workers in the Chemical Valley), the Community Awareness and Emergency Response Board (which notifies the community, including the Aamjiwnaang First Nations Reserve, about emergency spills or emissions), and the Chamber of Commerce (which represents about one-third of the businesses in Sarnia).

The politicians take a leadership role in many causes that affect their communities including protesting against land being set aside for windmills, advocating for developmentally delayed and disabled persons, lobbying for rail transportation at the federal level, ensuring high standards for landfill sites, raising money for the local college's expansion and renovation, and passing smoking by-laws. But in this context, the major leadership role of the politicians was to act as the broker between the needs of the community and industry, and the community felt that few of the politicians took on this difficult role. It has been seen as politically dangerous to stand up to the petrochemical companies who are so important to the community, although none of the interviewees expanded upon what consequences they might face if they did take on an advocacy role.

Social and Organizational Networks

Social and organizational networks are regarded as essential for community change. They act as resources, spread awareness, create a critical mass of protest, and demonstrate power. When networks are active, they improve literacy in dealings with industry, government, and occupational and environmental exposure science; provide social support and increase members' sense of power (self-efficacy);[31] provide financial support; increase access to peripheral networks; and share technology, training materials, and professional expertise. They are also essential when it comes to effective advocacy for occupational health and safety.

Most participants, when speaking of the past, remembered becoming aware of occupational exposures as a result of interpersonal interactions across groups. The "social construction of knowledge" is a key concept in KT. The participants spoke about the exchange of knowledge that occurred between groups, and strong bonds that were created between the union activists and the community, which led to the creation of the VOCV and in turn led to the media becoming aware, the industry getting involved, and hence even further heightened community awareness.

However, when participants spoke about connections in the present, they said that the link between the unions, the VOCV, and the occupational health clinic is no longer strong. The unions created the VOCV, but community knowledge of that seems to have been lost over time. The annual walk for victims, organized by the VOCV is no longer well attended by union representatives or local politicians. The occupational health clinic is no longer a hub of community activity.

Skills and Resources

Having access to skills and financial resources are related needs for communities attempting to engender change. Respondents said that money was necessary to fund advocacy efforts; for example, money was needed for the occupational health clinics, union activities, access to the legal system, and to conduct independent environmental monitoring. A community activist credits her daughter's skills with computers as being essential in getting out the message to other community members.

Worker advocates also cited skills as necessary tools for change. Training and literacy in dealings with government and industry and knowledge of occupational and environmental exposure science were important. Some advocates felt ill-equipped to navigate these systems and wished that the public school system had "taught this stuff." One labor representative mentioned that the courses he had taken through the Workers' Health and Safety Centre (a Ministry of Labour-funded, but union-run, teaching center for unionized and non-unionized workers) were important because the information gave him a knowledge base to inform his advocacy efforts. Industry members cited their occupational health and safety programs, policies and procedures, and metrics and personnel as vital for ongoing delivery, monitoring, and improvement.

Scientific information was an important resource. The availability of data on mesothelioma rates, lung cancer rates, and mortality in Sarnia were cited as essential in leveraging the unions and the community to advocate for protection in the workplace. These data were used at the government level to initiate environmental regulations such as lowering occupational exposure limits (OELs). Industry used government guidelines along with internal data to ensure they were compliant. Advocates and union representatives acknowledged that regulations and legislation are important, but said that enforcement is usually lacking. The politicians were the most supportive of legislation as a resource, since it "gives advocacy efforts teeth".

Interestingly, in this context, the large room at the occupational clinic was considered a valuable resource for the different community groups to meet, network, and strategize. The large room with big windows that could comfortably seat about hundred people eventually was removed. Its loss was a very tangible indication that the advocacy role of the occupational clinic had been discontinued.

Individual and Community Power

The representatives of the different groups had different perceptions of their individual sense of efficacy, their group's power, and the power of other groups. Not surprisingly, the dominant theme that emerged was the perception that industry is the dominant power in the community. Support for this idea came from industry's role as the source of high-paying jobs, having many resources at its disposal including money, professional networks, legal resources, public relations departments, and so forth. In turn, the representatives from industry stated that they have attempted to balance this perception by engaging in multiple activities to improve their reputation in the community. The industry representatives said that they would like to be perceived as good corporate citizens and are also motivated by personal moral reasons. In recent years, they have demonstrated transparency by publishing ambient air quality data in newsletters, investing in emergency response systems, sponsoring community events, opening their doors during "Family Days," and creating community advisory panels. Their agents spoke about the respect they showed to the neighboring First Nation community, such as moving noisy activities away from the cemetery, keeping the community informed about leaks and explosions, and having regular communication. They acknowledge that more communication is always needed.

However, many labor respondents talked about job insecurity. Workers and retirees expressed concern that if they demanded improved health and safety, there would be retribution, such as getting fired, losing contracts, losing pensions, or even plant closures. Of note, trade workers felt particularly vulnerable to these power structures since they were not unionized, and a number said that if they advocated for improved working conditions, their contract renewal would be threatened. Finally, a few community activists stated their concern about speaking out against the companies due to a potential backlash on their personal or professional lives.

Interestingly, although politicians are expected to have power, and although Sarnia's local politicians were involved in multiple matters that affected their community, most did not feel they had the power to affect change on a provincial or national scale. They felt "disconnected from Queen's Park" (the site of Ontario's provincial legislative building) and felt that their community's advocacy and initiatives were irrelevant to higher levels of government.

Shared Values, Beliefs, and Opinions

Sharing values, beliefs, and opinions is considered essential if different groups are coming together to advocate for change. There needs to be a fundamental agreement on what change is necessary, and why. The overarching values expressed by participants were split between social justice and business values; occupational and environmental justice was included in social justice. While some groups identified predominantly with one value-set, many spanned both. The clearest and most commonly expressed value of worker's rights came from labor activists or from community members who had a family member afflicted with an occupational disease. They felt that industry had an obligation to ensure a safe and healthy working environment: "There's something wrong when a person commits their life to an employer and their reward for it is to lose the last part of their life," said a unionist. While all industry members acknowledged this responsibility, some argued that it was a two-way street; workers should also take responsibility to protect themselves by using supplied personal protective equipment and following the occupational health and safety (OHS) regulations set out by their workplaces.

An idea, mostly mentioned by the labor group, was the concern that the values that are foundational to OHS and the need to be profitable are often in opposition, and that the companies were resistant to investing in OHS, as it would have a negative effect on profitability. Although more commonly expressed by labor and community representatives, some industry representatives also mentioned that industry cared only about "the bottom line" or profits to the exclusion of consideration for OHS.

A different perspective on values was expressed by industry members who commonly talked about business ethics, accountability, transparency, and responsibility in relation to OHS and the environment. They understood that protecting workers and the environment was a necessary part of running an ethical business, and examples of these values were given by all industry members. The other three groups echoed these values when they supported worker and environmental justice, objective monitoring of industry to ensure accountability, increasing transparency on the inner workings of industry, earlier and more transparent notification of spills and emissions, and taking responsibility for past actions that have led to poor health and negative environmental outcomes.

Perseverance

Individuals spoke about their personal and group perseverance in terms of grassroots advocacy efforts and the need to continue to protect workers' health and safety. Community members and the workers spoke about their ongoing struggle to increase awareness and change community norms around occupational illness. "I think you need to constantly be bringing it up to the public and having a lot of public input and just keeping it out there because I think people get complacent," said a community member. Although the ability to persevere in any change initiative over many years and against multiple obstacles was cited as an important tool for change, many advocates admitted that it has been tough to maintain. A worker advocate who was very active in the early 2000s has slowed down and reluctantly admitted that, "to re-engage, to truly re-engage ... is a big effort." In contrast, advocates and industry members alike expressed that a big event such as a death, tragedy, or industry spill can renew one's vigilance. Some of the community members said that the companies expected (and depended upon) community advocacy efforts "petering out" over time due to emotional burn-out, career responsibilities, personal health problems, family demands, and leisure activities. Despite how difficult it was for advocates to persevere, things like social support and professional leadership were cited as resources that made it easier to continue.

Others who are still working in or tied to industry spoke about the need to keep focusing on this issue. "Sometimes complacency sets in after long periods of time when nothing's happened," said an industry member. When industry representatives spoke about the need to maintain vigilance in OHS, they included the need for continuous improvement and monitoring of workers using their personal protective equipment. The reasons for this approach included protecting workers, improving their reputation in the community, disseminating safety culture, and avoiding the horror of relaying the news of a husband or father's death to the family.

Fulcrums of Change

This study inquired how a community progressed from the awareness of the health impact of asbestos to taking action to achieve support and compensation for workers who had become ill from workplace exposures. We attempted to identify the pivotal facilitators and barriers that the community encountered. We also explored whether this awareness about asbestos continued or transferred to other chemical industry-related hazards in the workplaces and the community. Unfortunately, the answers did not emerge with clarity. Alternatively, a case study emerged about how a community, at a certain point in time, with the help of the unions, attempted to raise the awareness of occupational exposures (asbestos in particular) and achieve community-level action. The four groups—labor, community, local politicians, and industry—had different perspectives on whether change was needed, and if so, what change, and what they saw as the essential tools, or necessary resources to help achieve change, or as we have called them, the "fulcrums" of change.

Labor

In the labor group, there was a strong division between those who were grateful to the companies and others who resented having been exposed to life-threatening occupational hazards. Most interviewees were happy with their good jobs, wages, and work environment. For the most part, they have enjoyed their work and have had successful and fulfilling careers, and hence they have an overall satisfaction with the status quo.

Most of the workers acknowledged that there has been a significant and notable decrease in occupational and environmental exposures over the last two decades. Many workers stated that workplaces are now much better places to work than they were in the past. However, it needs to be noted that many of the interviewees, but especially those in the labor group, indicated that they believe that profits and productivity fuel the decision-making in industry, and that any improvements that have been made to reduce occupational and environmental exposures, and hence occupational illness, have often been unintentional (although advantageous) outcomes of the profit motive. As one worker said,

> Industry's going to make more product, so they're going to upgrade their plants because they can sell more. Oh, while they're doing the upgrades they're going to buy new seals and new pumps and they're all state-of-the-art and they don't leak like they used to, etc. So those health risk changes come about incidentally.

The labor interviewees also spoke about the fact that even though exposure to asbestos is no longer the huge issue that it once was, workers are still exposed to a cocktail of chemicals, including benzene, that are potentially even more toxic to their health than asbestos (although the latency period between exposure and developing cancer hampers scientific investigation). However, this awareness does not act as a barrier to doing work from which they get enormous satisfaction. One worker described his work with great glee:

> Pretty much if it's nasty and can kill you, I'm the person who's going to be working with it.... Every year we [deal with] more interesting chemicals. I recently did my first nitrogen transfer with hexane, two weeks ago, and that's extreme! It's like 10 times more flammable than gasoline. So that was a fun one!

Most thought it was reasonable that the cost of a good job for more than thirty years might be illness and death: "We live ourselves to death. I hope that's the way I go", as one worker said representing the views of many of his colleagues. These workers were not angry with their companies—an attitude that is consistent with decades of OHS research and activism that shows that workers accept dangerous work as just "part of the job" rather than as something that can and ought to be prevented. They also emphasized how much worse occupational exposures had been in the past, and many considered occupational hazards, and exposure in particular, as a "legacy issue" that had now been solved. "Yeah, to me it's 100% better than it was in the '50 s and '60 s", said an older worker. Interestingly, many of these workers did not acknowledge the role that the unions, or OHS activists have had in achieving these gains.

But a sense of gratitude to industry for their well-paying jobs, sometimes an expression of satisfaction at having exciting work which was often dangerous work, and focusing on the improvements that have occurred over the decades, was not expressed by all. Another voice from the workers expressed anger toward the companies and blamed them for not doing enough "when they could have and should have" prevented a human health disaster.

The activists from labor expressed pride in their achievements from the late 1990s. They gained significant media exposure on the devastating effect of asbestos on the health of the workers, they held intake clinics for workers, and through the occupational clinic, obtained compensation for more than 700 workers. Those who were involved reflected on that time with a sense of awe and wonder at what they had achieved. Notable was getting the funding to establish a permanent occupational clinic in Sarnia. "There was a resolution to have the [occupational] clinic funded fully. We were surprised when they actually did fund it fully."

However, when these changes were taking place there was a strong and large union membership in Sarnia and the leadership of multiple unions came together to help Sarnia and its sick and dying workers. The unions were well connected to the community and shared their values. They became well informed and were resourced by their national membership. This base of power has since been eroded by the precipitous decrease in unionized membership and the threat of plant closures and layoffs. Consequently, in the decades since the unions rallied to help the community, the union leadership has been diverted to more urgent survival issues; examining exposures that might have a latency period of thirty years or more has dropped in their priorities.

Community

The participants who fell into the "community" group were the most diverse. Nevertheless, themes did emerge. The community members saw the major fulcrums of change as leadership, credible research, a sense of their own power, and the endurance and perseverance to keep focused over many years. But they did not necessarily share values, opinions, and beliefs. Those who had been directly affected, including falling ill themselves or losing a loved one, were the clearest in their ideation that the companies had failed in their responsibility to care for their workers. However, a conflicting theme that emerged even from the widows in this group was that their late husband had had a good job, had given their family a good life, and now that compensation was available, he was still looking after them.

The VOCV have made occupational illness their own personal battle and continue to be angry with the companies, with their community which they perceive as turning complacent, and the lack of leadership from the unions to help continue the crusade. As one said: "I just want it all fixed. I know that we can't change the legacy of the past. I know that we can't do that. But my goodness... it's not ok anymore. I'm not disposable, you know." The VOCV continue to lobby for awareness and action on the dangers of exposure to asbestos. Recently they changed their name to the Victims of Asbestos and Occupational Exposures, acknowledging that there are other dangerous chemicals in the petrochemical industry to which workers continue to be exposed, and potentially expanding their advocacy beyond Chemical Valley.

The other community groups have other issues on their mind (health, education, employment) and thus occupational exposure, regardless of its high profile in the city, is no longer their priority. Having workers die early has become part of the accepted background of living in the city. A member tried to explain, "This is our normal. This is what we live every day, and, oh well, some day it's going to kill me!"

The community activists are proud of what they have achieved, but the change process has been long, and many of the community members are now tired and discouraged and weighed down with other responsibilities. As another stated in despair, "You know, by the time all of [the political lobbying] unfolded, I was ill. Like really sick. To the point that for weeks and months I could hardly stand. I stopped my [advocacy] work."

Local Politicians

The politicians who contributed to the study were representatives at the city level. In regard to "the asbestos problem," the Mayor of Sarnia, Mike Bradley, took the lead within this group in raising awareness and supporting the victims. As early as 2001, he led an initiative for Sarnia City Council to endorse a resolution requesting the Federal and Quebec Governments to ban the exports of asbestos outside of Canada. Sarnia was the first city to officially make this plea to the Canadian federal government. In 2008, the Council reaffirming their position to once again call upon the Federal Government and the Government of Quebec to stop the export of asbestos out of Canada. In September 2011, on the tenth anniversary of the first resolution, the Mayor again led the Members of Council to reaffirm their resolution and support a Candlelight Vigil and a Walk "to bring the community together to demand the Federal and Quebec Governments stop the export of asbestos".[32] By 2013, Canada had stopped exporting asbestos.

The local politicians were very self-conscious of the limitations of their power to make major change at the municipal level since decisions about occupational or environmental legislation, transportation, or location of major industries are made at the provincial level. A representative quote was: "As far as taking a leadership role and going out and beating a drum and trying to make something specific happen, only in my own municipality for my own people is the limit of what I do."

The local politicians said that they were obliged to consider the multiple voices in their city. There were many other issues that took priority over occupational exposures and illnesses, such as the need to get the college funded; the need for a railway link between Sarnia and London; the need to reopen the jail; the need for a top quality hazard landfill site.

There were mixed results depending upon whether the community was talking about the local politicians, or whether the politicians were reporting on their own actions. Key activities in support of awareness of the occupational and environmental impact of industrial emissions included: participating in the annual community Walk to Remember Victims of Asbestos, and supporting the pending Community Health Study to examine the impact of environmental emissions. The Council has recently supported the remediation of a park that is heavily laced with asbestos, lead, carcinogenic hydrocarbons, and metals; the remediation plan and execution has been done with relative speed because of the high awareness that the community has of asbestos. However, even these issues are not supported by all councillors. One of them admitted in amazement that he had heard this comment from a peer in regard to the park: "Just take the fences down and let people take their chances."

What is considered most important by most of the local politicians is a thriving petrochemical industry. Industry supports the city in tangible ways by offering employment but also by contributing to the college, the hospital, and ceremonies to celebrate the city's 100th birthday. The reputation of the city is also important. The politicians are working on rebranding the community so that it is no longer synonymous with "Chemical Valley." They are considering ways to diversify the economy including attracting the alternative energy sector, expanding applied health-care training in the local college by extending nursing training to four years, and attracting a retirement population. They are upset that the media will not report on the "good news" stories of how the community has improved. To bring occupational exposure back onto the radar for this group, the community would have to yet again build this issue as a major focus. It would have to be a bottom-up movement.

Industry

The industry representatives all mentioned that acute injuries were a strong priority for them, and they have policies, procedures, and programs in place to prevent these. However, they all commented that initiating policies, procedures, and practices to reduce occupational exposures (which are from chronic exposure) is not equally straightforward. Decisions on occupational exposures need to compete with multiple competing priorities: Immediate safety issues take priority over long-term exposures; research evidence on the health effects of chemicals and processes can be confusing; risks versus hazards need to be balanced; how to best handle existing asbestos remains an unresolved issue; the substitution of chemicals and processes can be very expensive and not necessarily less toxic to workers; keeping up with the regulatory environment in Canada, which is more stringent than that of other countries is already a competitive issue; the shareholders need to be pleased, and hence, the highest priority remains productivity. As one of the managers said:

> At the end of the day, you're faced with a whole myriad of pressures and things to consider before making a decision. And it's difficult.... Small stuff we can do, and we continue to do. And even some of the big stuff we do, which is part of [our company's] commitment. But it comes down to [making decisions based on a] matrix of frequency and severity.

Since many of the companies in Sarnia are branch-plants of multinationals, the companies' safety standards are usually set by head offices that are not in Canada. Health and safety programs are evaluated by metrics such as lost-time injuries. However, that does not preclude the role and the power of the individuals themselves and the actions they take to make change at the local level. As mentioned, as a group, the eight industry participants who are plant managers, engineers, production managers, and health and safety specialists, see themselves as leaders in the community in monitoring and reducing short- and long-term occupational exposures and environmental emissions and are making some significant changes to improve their standing in the community and on safety in their plants.

Some mentioned how a critical incident in their past had led them to focus on safety,

> I've been involved with fatalities and having to go and talk to families. The most recent one was after a mother was killed at work. Not her fault, but an accident at work. Talking to [children] about their mother passing away, and speaking at her funeral was tough. Don't want to ever do that again.

Others mentioned their love for their work.

> I like to make plants run really well from all aspects: safety, environmental performance, reliability, profitability. I like being part of keeping manufacturing alive in Ontario and keeping valuable jobs in Ontario and value added, like the contribution we make to the economy.

Summary

The "story of Sarnia" which emerged from the interviews and focus groups is that, beginning in 1996, there was community- and union-led organization to recognize the health effects of exposure to asbestos in the workplace. Emerging from this concerted effort were a number of benchmark changes that have made a significant improvement in the lives of the sick workers, the widows, the surviving children, and the community in general. Compensation is now awarded relatively easily to workers from Sarnia with cancer or their survivors. A hospice was built for sick and dying workers. An occupational clinic achieved permanent status in the community. Environmental monitoring is now conducted regularly. There is a more collaborative relationship between industry and the neighboring First Nations community. The economy is beginning to diversify. At a smaller level, local funding has been secured for the Centennial Park remediation, and a third of the needed funding has been secured from the petrochemical companies for the Community Health Study. According to the conceptual framework (See Figure 1), these changes will hopefully lead to an overall reduction in occupational exposures, improved remediation, and ultimately, improved worker health.

To achieve these community-level changes, union and community leaders formed partnerships and mobilized their social and organizational networks. Then, grassroots activism emerged that engaged the media which increased the pressure on industry. Finally, the resolution to fund and make permanent the occupational clinic sparked the beginning of the community-level changes.

The successful campaign to raise awareness about the carcinogenicity of asbestos was dependent upon a number of factors. First was the clear, concrete definition of the issue and its easy communication throughout the community. Irrefutable evidence shows that asbestos causes asbestosis, mesothelioma, and lung cancer. Asbestos was widely used throughout the sector, with workers at the Holmes Foundry and Fiberglas Canada being particularly vulnerable.

Second, a confluence of events helped raise awareness of this problem and supported the action. The city had credible leadership, an educated workforce, social and organizational networks, skills and resources, individual and community power, shared values, beliefs and opinions, and perseverance. At the time, there was a large population of unionized workers. This circumstance gave the Communications, Energy and Paperworkers Union of Canada (CEP), and the Canadian Auto Workers (CAW) (who have now merged into a new union called Unifor) the power to initiate change. A union representative, with the support of the CEP leadership and the larger provincial labor federation (the Ontario Federation of Labour), took on the project of supporting sick workers and bringing them together to map their exposures. A leader with knowledge of the health effects of asbestos and external credibility was introduced into the community and took over management of the occupational clinic. A union leader helped create a widows' support group, the VOCV, which had the moral and emotional authority to challenge the status quo and could enroll the local media. The unions and the Clinic helped hundreds of workers and widows file for compensation.

Sarnia is a small, relatively isolated, homogeneous city heavily dominated by the petrochemical industry. It was small enough to be well-connected, and it was rare for someone not to know of or be directly affected by the illness of a worker, and hence it was feasible for the whole community to feel involved in the issue. The community- and union-supported occupational clinic became a hub for community meetings and action. There was political support especially from local senior politicians, and this helped increase media awareness. When the campaigning started, the companies were operating in a successful economic climate and hence possibly were more able to change practices and processes. Not mentioned by any of the interviewees, but relevant nonetheless, is the number of environmental regulations that were introduced at this time.

However, the concerted community and union effort to reduce workers' exposure to hazardous chemicals is now all but over. Although asbestos remains on the radar in the community and continues to be influential, as demonstrated by the speed with which the remediation of Centennial Park has been undertaken, the advocacy effort and the strong collaboration on the issue of occupational health and safety between the unions and the community has all but ceased. Asbestos has now been relegated to be a legacy issue. This may be a reasonable conclusion as demonstrated recently when this group of researchers engaged eight union locals in Sarnia to "find" sick and ill workers over a three-month period, who thought they may have been exposed to asbestos but had not yet filed for compensation, and none were identified (publication in process).

What is less clear is why the awareness of the carcinogenicity of asbestos has not generalized to other occupational health and safety issues. Workers in the petrochemical sector are still exposed to a variety of dangerous chemicals that are potentially carcinogenic. However, the research to determine the causal link between those exposures, and cancer is at present not as strong as the body of research on asbestos and cancer. The causal link between these other exposures and cancer is probably more nuanced and potentially multifactoral and hence the awareness of potential harm is not as high, as it was of asbestos.

Another reason why the action on asbestos has not generalized to other workplace exposures could be because of wider external climate factors that were not mentioned by the interviewees. Globalization, automation, and even free trade have led to companies closing down in Sarnia and a severe reduction in the unionized work force. There has been a concurrent erosion of union power. Unemployment and job and food insecurity has also become an issue in this previously wealthy city. The social, political, and economic climate in Sarnia is no longer as supportive of worker rights as it was fifteen years ago, nor is there the same level of community support. The leadership that was active then has been diminished; there is only so much perseverance an individual can maintain, and interviewees told us that a younger generation of leaders has not yet emerged.

Lessons Learned

This exploratory study has limitations. It is a unique case study of a small city with one major industry which was afflicted with an intense exposure to one lethal occupational carcinogen, asbestos. Since many of the interventions that can reduce workers' exposure are dependent on workplace parties, the recruitment process emphasized industry management, and union representation. The thirty interviewees and participants in the focus groups were a convenience sample recruited with the help of the research team's existing network. The Aamjiwnaang First Nations Reserve who live within the boundaries of the city and have been very affected by the industrial environmental emissions were under-represented in this study. Only four First Nations were interviewed. Future research may potentially remediate this lack.

Despite its limitations and its potential lack of transferability, this study may offer advocates of change and the field of KT some useful ideas. The study points to the importance of empowering people or the community, the role of strong stakeholders, and the use of clear and strong messages, backed by credible research, directed to the outcomes/impacts on workers' health, in order to be successful in advancing social justice.

Another is that it is important to have champions and leaders who have supportive organizations or unions. They will provide the power and perseverance needed, even if the demand for change takes years and individuals falter. The other relevant points are linked: ensure that the person/workplace/community has the skills and resources to advocate for and make the change; ensure that all the relevant stakeholders are networked, linked, and engaged; and build a body of shared values, beliefs, and opinions and a sense of community by building alliances and working in solidarity on a focused mission. This will, in turn, create the groundswell of support and the critical mass for change that is needed to bridge the gap between awareness and action.

The third lesson of this study is that the timing is everything. Good advocates know that they must be ready to identify a rising trend and be ready to catch the wave of change. It is not all about the strength, power, or leadership skills; sometimes the times are not right. Even the most charismatic leaders will not be able to make change if they are not supported by a strong organization, whether community, union, political body, or company. The late 1990s were a good time for occupational health and safety in Ontario, with improvements occurring at multiple levels including new legislation. This provided a good backdrop for the activism in Sarnia. The remaining activists in Sarnia are hoping that equally auspicious times will return.

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Mike Bradley was first elected to Sarnia Council in November of 1985 and was elected as Mayor in 1988. In 2014, he was reelected for his ninth term with a 66% majority. He currently serves on six boards in the Sarnia-Lambton municipality. He has received over ten awards over the past decade for his promotion of workplace health and safety.

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Features

CHEMICAL EXPOSURES OF WOMEN WORKERS IN THE PLASTICS INDUSTRY WITH PARTICULAR REFERENCE TO BREAST CANCER AND REPRODUCTIVE HAZARDS*

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ABSTRACT

Despite concern about the harmful effects of substances contained in various plastic consumer products, little attention has focused on the more heavily exposed women working in the plastics industry. Through a review of the toxicology, industrial hygiene, and epidemiology literatures in conjunction with qualitative research, this article explores occupational exposures in producing plastics and health risks to workers, particularly women, who make up a large part of the workforce. The review demonstrates that workers are exposed to chemicals that have been identified as mammary carcinogens and endocrine disrupting chemicals, and that the work environment is heavily contaminated with dust and fumes. Consequently, plastics workers have a body burden that far exceeds that found in the general public. The nature

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of these exposures in the plastics industry places women at disproportionate risk, underlining the importance of gender. Measures for eliminating these exposures and the need for regulatory action are discussed.

Key Words: plastics workers, women's occupational health, breast cancer, endocrine disrupting chemicals

Women employed in the plastics industry are exposed to a multitude of toxic chemicals used in plastics production. These include styrene, acrylonitrile, vinyl chloride, phthalates, bisphenol-A (BPA), brominated flame retardants, heavy metals, a host of solvents, and complex chemical mixtures. Recently, public health concerns have emerged about the toxic qualities of substances contained in consumer plastics and their potential impact on children's and women's health.

Growing evidence of harm has led to public health initiatives in several jurisdictions to ban or restrict the use of these substances, in particular phthalates, BPA, and brominated flame retardants. Extensive biological monitoring campaigns have been launched to track the uptake of these chemicals in the general public. Despite this response to growing evidence of adverse health effects, little attention has been paid to the potential health impacts on more highly exposed plastics workers. Indeed, it comes as no surprise to see body burdens of these substances in workers that are significantly higher than those measured in unexposed workers and the general population [1- 6]. In this latter regard, it is important to note that levels currently detected in general populations can produce adverse effects in laboratory animals.

Our review indicates that women are at disproportionate risk due to the types of jobs they perform in the plastics industry and their particular biological vulnerabilities. Reflecting the general position of women in society, women perform the more labor-intensive jobs in the industry compared to men, who are more likely to work in the trades or to have supervisory roles. Of major concern is that occupational exposures to chemicals used in the plastics industry may contribute to the development of breast cancer and reproductive problems, because they either act as mammary carcinogens or disrupt the normal functioning of the body's endocrine system, or both. A recent study found that most plastics products release estrogenic chemicals [7]. Such endocrine-disrupting chemicals (EDCs) as phthalates, brominated flame retardants, and BPA are ubiquitous in the plastics work environment. Importantly, action at the endocrine level is such that significant adverse effects can be produced at concentrations thousands of times lower than the presumably safe levels established by traditional toxicology. For example, a dose of BPA that is 2,000 times lower (0.025 μg/kg/day) than the reference dose for human populations (50 μg/kg/day) can stimulate mammary gland development in animal offspring whose mothers were exposed to this low dose [8, 9]. To compound the issue, plastics workers are exposed to complex mixtures of a large variety of chemicals and combustion byproducts—described by a plastics worker as a "chemical soup"—whose combined effects may be greater than the sum of their individual effects on health.

This article is meant to sound an alarm about a major occupational health hazard that has not received adequate attention from the medical, scientific, and regulatory communities. To this end, we explore what is known about workplace conditions in the plastics industry, what is known about worker exposures to substances in the production process and their impact on women's health, and whether regulatory standards are protective. Finally, we offer some recommendations for changes that are needed.

WOMEN WORKING IN PLASTICS PLANTS

The link between chemicals used and/or produced in the plastics industry and the risk of breast cancer and reproductive harm is of particular concern because the plastics industry has a very high concentration of women workers. In Canada, for example, the plastics industry has a higher proportion of women workers than any other industry in the manufacturing sector, comprising 37 percent of the workforce [10]. In some areas like Windsor-Essex County in southern Ontario, where many plastics products are produced for the automobile industry, women constitute the majority of the area's plastics workforce [11].

Similarly, a high percentage of women work in plastics-related industries in the United States: almost 30 percent of workers manufacturing plastics products, one-third of the workforce producing rubber products, and one-quarter of the workers in the resin, and synthetic rubber, and fiber industry are women [12].

For the most part, the Canadian industry is dominated by small plants, 75 percent of which have 20 or fewer employees [10]. Many of these plants are not unionized, are economically marginal with low technological development, and have precarious employment as a result of the restructuring of manufacturing in the global economy.

THE PLASTICS PRODUCTION PROCESS

Plastics consist of polymers composed of long chains of repeating monomers. They are produced through multiple steps in different occupational settings, and workers are exposed to chemicals of concern at various stages of processing.

There are three basic stages of production and several different types of plastics manufacturing processes, as described in the *Concise Encyclopedia of Plastics* [13]. In the first stage, monomers such as vinyl chloride, styrene, BPA, acrylonitrile, butadiene, ethylene, and urethane are formed by processing crude oil and/or natural gas through a method the petrochemical industry calls *cracking.*

In the second stage, the resulting monomers are sent to resin producers to undergo the process of polymerization. Polymerization involves a chemical reaction in which the molecules of a monomer such as vinyl chloride are linked together to form large molecules with a molecular weight many times that of the original monomer. Resin producers convert monomers into polymer products such as polyvinyl chloride, polystyrene, nylon, acrylonitrile-butadiene-styrene (ABS), and polyurethane. Resins are then shipped to plastics products manufacturers in the form of powders, liquids, or pellets. In the third and final stage, polymers are processed by downstream industries to make paints, adhesives, and plastics products such as pipes, packaging, automotive parts, toys, fabrics, siding, medical equipment, and tools.

Polymers are divided into two main classes: thermoplastic and thermoset. Thermoplastic polymers can be repeatedly softened and reshaped with the application of heat and pressure. Common examples include polyvinyl chloride (PVC), polyethylene, polystyrene, and acrylics. In contrast, thermoset materials such as epoxy undergo a chemical reaction that results in a permanent product that cannot be softened or reshaped. Well-known thermosets include polyurethane, phenolics, ureas, and epoxies. Using one of these two classes of processing, resins are formed into different plastic products.

Among the several methods used to fashion plastics products, injection molding, reaction molding, and foam molding best illustrate the major techniques used to process thermoplastics and thermosets.

Injection molding is the most widely used technology to process thermoplastics. In this process, polymer resins in the form of pellets are injected into a screw feed chamber where they are melted and carried under high pressure into a mold of desired shape. Once cooled, the parts are ejected and retrieved by workers who typically trim, drill, grind, sand, paint, and decorate the part into a finished plastic product.

Reaction molding is similar to injection molding except that the thermosetting polymers that are used require a catalyst and a curing reaction within the mold. Polyurethane is a widely used thermosetting polymer.

Similarly, thermoset foam molding involves injecting a chemical mixture into a mold where it reacts and expands to fill the mold with thermosetting cellular plastic. During processing many other materials are added to alter the resin's properties. These additives can include heavy metal stabilizers, phthalate plasticizers, antioxidants, blowing agents, lead or cadmium pigments, brominated flame retardants, curing agents, and lubricants.

EXTENT AND NATURE OF WORKERS' EXPOSURES

Workers' Reports on Working Conditions/Exposures

The extent of workers' exposures is determined by their job tasks and the quality and existence of exposure controls in the plants where they work. During every step in the plastic production process, contaminants are released as a result of the handling and mixing of resins and additives, and their processing under high heat and pressure. Gases and vapours containing residual monomers, as well as additives such as phthalates, heavy metals, flame retardants and various hydrocarbons, are released during venting and normal processing. Additional dust and vapours are produced during finishing operations containing various monomers, additives, solvent and paint fumes. At the same time, the overheating of plastics during machine malfunctions and purging operations results in thermal decomposition and the release of chemical byproducts. In contrast to monomer and resin production, which typically employ closed-looped containment systems that keep material handling to a minimum, molding and fabricating are relatively open operations permitting the release of contaminants into the work environment. These production jobs are typically labor-intensive and are more likely to employ women.

Detailed descriptions of workers' exposures in plastic production are limited. Published research seldom contains data describing typical, day-to-day conditions as experienced by workers themselves [14]. A case-control study of occupational exposures and breast cancer being conducted by Brophy et al. in Southwestern Ontario, Canada, required qualitative data to inform its exposure assessment and coding process for several occupational environments, specifically agriculture, health care, and automotive manufacturing, which includes plastic parts production [15]. A qualitative study was undertaken concurrently to gather the required information. The study and its methods were approved by the research ethics board (REB) at the University of Windsor, the host institution. Experiential data were gathered between 2008 and 2010 through individual and group interviews [11, 16]. Utilizing the same approved methods, supplementary group interviews were conducted in 2011 in collaboration with the National Network on Environments and Women's Health. Local unions representing plastics workers and the Canadian Auto Workers union national office assisted in the recruitment of a total of 40 individuals from 13 local plastics plants in Windsor, Ontario, for the study and supplementary interviews. Facilitated discussion included open-ended questions about the participants' working conditions, job tasks, plant layout, chemicals used, protective controls, changes that occurred over time, exposure concerns, improvements needed, and perceived barriers to gaining improvements. One of the data-gathering techniques used was *hazard mapping*. This approach has been validated in other occupational health studies [17, 18]. Such visual representations enhance participants' recall and can result in rich, detailed descriptions of the current and past work environment. The interviews were audiotaped and transcribed.

The first-person accounts, which are reported without participant identifiers, revealed personal experiences regarding usual practices and related exposures, as well as malfunctions. For example, one of the study participants described her experience during a routine molding machine malfunction: "I looked behind the mold and I could see a big cloud of smoke and then there was a fire and . . . the smoke is clearing and here is one of our workers standing in the middle of it. You couldn't even see her and it was just plastic burning" [16].

The study included a review of a small collection of government and company hygiene consultant reports provided by members of the plastics workers' union health and safety committee [19, 20]. These reports were related to various inspections carried out in several of the workplaces represented by study participants. The inspectors and consultants reported conditions similar to those described by study participants. For example, a common concern expressed by study participants was the lack of ventilation. A participant commented that "We do plastic injection molding. We smell a lot of smells, a lot of fumes, stuff like that—so I'd like to see actually more local exhaust" [16]. Hygienists and government inspectors reported that the machines they inspected were releasing chemicals into the air and that local exhaust ventilation is rare. A 1995 Ontario Ministry of Labour report investigating worker complaints from ABS injection molding machines documented releases of acrylonitrile, benzene, styrene, acetaldehyde, xylene, and toluene [19]. A hygiene consultant visiting an Ontario plastics plant in 2004 reported: "different odors were perceived in different units of the plant and mold injection units were not equipped with local exhaust ventilation" [20]. One woman working in a plant with poor exhaust ventilation described the following effects: "I don't know if it's from the smoke or if it's from the fumes. You smell fumes, you taste [it] in your mouth, and then you get—it's like a light-headedness, dizziness" [16].

Before packaging and shipping, molded plastics are trimmed, drilled, and sanded; some also need to be assembled, painted, and decorated. Workers performing these tasks can be exposed to polymer dust from sanding and grinding operations as well as to paint and solvent vapours. Workers noted: "while on assembly near decorating, the parts were frequently spray-painted with gray paint. Since we were close by, we would also get a dose of spray-paint all over us. It was everywhere. We would look like the 'Tin Man' in the Wizard of Oz" [16].

Workers handle various plastic fabrics impregnated with flame retardants and phthalates used in car interiors during the finishing process. Exposures can be intense, as one worker observed: "When stitching fabric we would be encased in dust. When you blew your nose the mucus was loaded with this dust. It was treated with antimony trioxide and [tris (2-chloroethyl) phosphate, a flame retardant commonly known as "tris"]. We have skin and breathing problems. The material was still wet with this stuff when we worked on it" [16]. A government inspection report regarding the process described by the worker noted: "There is no exhaust ventilation on 3 of 4 sewing machines and it appears dusty" [19]. The inspector suggested improvements, but did not issue orders.

The overheating of plastic materials is another source of polymer fumes, smoke, and gases not only during processing, but especially during cleaning, purging, and maintenance operations. When molding machines are cleaned and purged, resins and purging agents are forced through plastic presses at very high temperatures.

Workers interviewed about their experiences said that when the machines were purged, "hot stinky gunk would sit there and off-gas" [16].

Although inspection reports and workers' observations indicate that dust and fumes were constant problems and ventilation was inadequate, often hygiene sampling did not find levels above the occupational exposure limits (OELs). As one woman commented: "The Ministry comes in and does testing and it's never over the exposure limit. We would run ABS and there were people suffering from symptoms and the test results always came back under what was allowed" [16].

On rare occasions, air sampling showed that contaminants did exceed acceptable levels. A government inspection of a Windsor plastics plant in 1990 found volatile organic compounds to be above the short-term OELs. The inspector noted: "Exhaust fan in the gluing booth, exhausts . . . inside the plant and air is re-circulated. With increase in production, large amounts of solvent vapors are produced" [19]. The inspector recommended that the booth exhaust air be directed outside, but no orders were written to the company despite the clear violation of the Regulations under the Ontario Occupational Health and Safety Act, which prohibit exhausting contaminated air into the work environment—a regulation that had been in place for over 20 years.

Toxic Body Burden

Although the authors do not advocate biological monitoring or the use of biological exposure limits as a means to protect worker health, we reviewed literature that compared the body burdens of EDCs found in studies of workers with those found in studies of the general population. Since the experimental work of endocrinologists shows adverse effects at levels found in the general population, these comparisons were used to assist in assessing occupational risk.

Our review of the biomonitoring studies found that workers involved in plastics processing have chemical body burdens significantly higher than those found in "non-exposed" referent groups or the general population. The chemicals measured included acrylonitrile, styrene, phthalates, and BPA. A Dutch biomonitoring study of plastics workers found that exposed workers had average acrylonitrile (AN) concentrations in urine that were 11 times higher (AN/U 22.1 μg/g) than the average concentration found in non-smoking/non-exposed workers (AN/U 2.0 μg/g), even though air concentrations for exposed workers at the workplace (AN/A 0.13 ppm) were below the established limit (AN/A 2.0 ppm) (AN/A 4.0 ppm)/MAC-TWA in the Netherlands and 2 ppm established by the U.S. Occupational and Health Administration at the time of the study. (These were calculations from the study's data for arithmetic means for non-smoking controls and non-smoking exposed workers.)These concentrations persisted on days off, indicating that AN was bio-accumulating [1]. Similarly, styrene has been found at elevated levels in plastics workers. An Italian study comparing blood-styrene levels found concentrations in exposed workers (1211 μg/L) levels 5.5 times higher than levels found in what the authors describe as a "normal" population (221 μg/L) [2]. Another Italian monitoring study found that job tasks were the most important predictor of styrene exposure, with levels of styrene in urine directly proportional to the level of manual handling of materials [3].

Phthalates studies provide another example of workers with high chemical body burdens. A study conducted by Liss and colleagues found significant uptake in workers exposed to di-(2-ethylhexyl) phthalate (DEHP) [4]. Researchers found high urinary phthalate concentrations even though air sampling failed to detect them. In metabolite studies that were combined with air sampling, urinary phthalate levels were significantly above levels found in general populations, even though air sampling showed levels far below exposure standards and in trace amounts [5].

Although few occupational studies have been published, BPA was measured in the urine of Japanese workers who applied epoxy resins containing bisphenol-A diglycidyl ether (BADGE) and found to be significantly higher in 42 exposed workers (1.06 μmol/mol) compared to 42 unexposed (0.52 μmol/mol) controls [6]. The authors noted that the levels found in controls were similar to levels found in the general population.

HEALTH IMPACT OF HAZARDOUS CHEMICALS USED IN PLASTICS PRODUCTION

It is generally accepted that the plastics processing work environment is potentially contaminated by residual monomers, polymers, and various additives, including plasticizers, stabilizers, pigments/colorants, flame retardants, activators, lubricants, and fillers, as well as solvents, paints, and finishing agents used in the decorating process. Some of these substances are mutagenic and known to cause cancer in humans, some are suspected of causing cancer, and some have been identified as endocrine-disrupting chemicals that may promote cancer.

Plastics workers have expressed concerns about their cancer risk. One woman from a Windsor plastics plant observed, "We've had quite a few women, one woman, actually right now is going through her treatment for breast cancer, started last week . . . and we've had four within the last ten years I would say. So yeah, it's always in the background of your mind when they're purging the machines. . . . We'll yell over at another co-worker and say I wonder what this smell is, if it can affect us" [16].

Monomers of Concern

Although monomers are generally used up during polymerization, residual monomers such as vinyl chloride, styrene, acrylonitrile, BPA, formaldehyde, butadiene, ethylene, and urethane can still be released during the production of resins or thermal processing [21]. A recent rating of the toxicity of various plastics substances, conducted by Swedish scientists, demonstrates the high degree of toxicity of many monomers [22]. Their study ranked 55 polymers used in plastics production according to degree of toxicity and seriousness of health effects based on monomer hazard classifications. Polymers of highest concern contained monomers classified as mutagens and/or known or probable carcinogens. Thirty-one of 55 polymers contained monomers belonging to the two highest hazard levels on a scale of five—in particular, polyvinyl chloride, styrene-acrylonitrile and acrylonitrile-butadiene-styrene.

Monomers, such as vinyl chloride and formaldehyde, are known to cause cancer, and are classified by the International Agency for Research on Cancer (IARC) as human carcinogens [23]. Vinyl chloride was first identified as the agent responsible for angiosarcoma in workers making polyvinyl chloride [24], while more recent studies show an association between vinyl chloride and testicular cancer [25] and possible association with male breast cancer [26]. Formaldehyde has also been linked to an increased risk of female breast cancer in a 1995 U.S. study of industrial workers [27].

Many monomers are found to be mammary carcinogens. In their comprehensive database of substances shown to cause mammary gland tumors in animals, scientists at the Silent Spring Institute in Massachusetts have listed three monomers used in plastics production: vinyl chloride, acrylonitrile, and styrene [28]. Styrene is the second-most-used monomer. Acrylonitrile has been linked to genital abnormalities in children born to exposed mothers and may have endocrine-disrupting effects [29]. Styrene, in addition to being a possible carcinogen, is identified as an endocrine disruptor [30].

Other monomers are either known or suspected of being EDCs with the potential to put workers at risk for breast cancer. The monomer 1,3-butadiene has been shown to induce mammary gland tumours in rats and has been classified by IARC as a Group 2A carcinogen [31]. The most well-known endocrine disruptor among widely used monomers is BPA. A large-scale literature review sponsored by the U.S. National Institutes of Health concluded that BPA concentrations in human populations were comparable to levels of BPA that produced "organizational changes in the prostrate, breast, testis, mammary gland, body size, brain structure, chemistry and behavior of lab animals" [32]. Studies demonstrate that significant effects can be produced by very small doses. For example, studies on BPA found adverse effects at doses far below referent levels for human populations. Some effects included mammary gland stimulation in offspring at maternal dose of 0.025 μg/kg/day, alterations in immune function at doses of 2.5–30 μg/kg/d, early onset of sexual maturation after maternal dose between 2.4 and 500 μg/kg/d, and decreased sperm production and fertility in males at maternal doses between 0.2 and 20 μg/kg/d [33-35, 8, 9]. These studies suggest that BPA may increase the risk of breast cancer and reproductive abnormalities in women. In this latter regard, human BPA studies have identified adverse effects in women with a high body burden that include recurrent miscarriages, ovarian cysts, obesity, and endometriosis [36-39].

Additives with Toxic Properties

Plastics workers are also exposed to numerous chemicals added to resins. Many of these additives have potentially toxic effects, and some are identified as either carcinogens or endocrine-disrupting chemicals or both. Of these additives, phthalates raise many concerns for workers in the plastics industry. The phthalate DEHP, used to plasticize PVC, may be estrogenic. It has been implicated in the development of male breast cancer and testicular cancer and may cause reproductive problems among both men and women who work in PVC fabricating operations [25, 26, 40]. A study of a phthalate-exposed population in northern Mexico found an elevated breast cancer risk among women [41]. A recent study of male PVC workers in Taiwan found an adverse effect on the semen quality among men with the highest concentrations of DEHP [42].

Heavy metal additives such as lead, cadmium, organic tin, barium, calcium, and antimony compounds used as pigments and stabilizers are highly toxic. Lead compounds are classified by IARC as possible carcinogens and cadmium is a known human carcinogen [23]. Lead is an endocrine disruptor with reproductive effects in both men and women [43].

Flame retardants such as polybrominated biphenyls (PBBs) and polybrominated diphenyl ethers (PBDE) are strongly estrogenic and some are classified by IARC as possible carcinogens [23]. Tris is identified as potentially "toxic to reproduction" [44]. Antimony trioxide has been shown to cause respiratory cancer in female rats and negative reproductive effects in humans [45] and is classified by IARC as a possible carcinogen [23].

Other Chemicals of Concern

In addition to the many carcinogenic and/or endocrine-disrupting chemicals used in thermal processing, there are several other cancer-causing and hormone-disrupting substances common to most manufacturing jobs. For example, polycyclic aromatic hydrocarbons (PAHs), emitted by machining, fuel combustion, and other decomposition processes, have been identified as mammary carcinogens in animal testing [28]. Benzo(a)pyrene, one of the PAHs produced when combustion is incomplete, has been classified by IARC as a human carcinogen [23]. The widely used solvents benzene, methyl ethyl ketone (MEK), and toluene have been found to cause mammary tumors in animals [28]. Researchers suggest that organic solvents may initiate or promote breast cancer, and many are considered to be endocrine disruptors [46].

Endocrine-Disrupting Chemicals and Windows of Vulnerability

Current exposure limits do not take into account possible effects at very low concentrations characteristic of endocrine disruptors, which typically range in the parts per trillion [47]. Flying in the face of the traditional toxicologic paradigm, EDCs may not exhibit a linear dose-response relationship. Indeed, endocrine researchers generally accept that in some circumstances low doses may have a greater effect than higher doses. The endocrine system is a sensitive system that regulates growth, metabolism, sexual development, and reproduction. It can be disturbed by very low doses of substances that can mimic or trigger estrogen—a very powerful tumor promoter linked to the development of breast cancer. Underlying the disproportionate risks to women workers is the fact that for substances that act through the endocrine system, sex and gender are critical. The timing of the exposure in relation to biological developmental stages is particularly significant [48]. There are critical windows of vulnerability where women may be more susceptible to the effects of endocrine disruptors, particularly those periods leading up to the end of a first full-term pregnancy, when breast tissue becomes fully differentiated [46].

Health Effects of Complex Mixtures

Plastics workers are rarely exposed to one substance at a time. Instead, they are exposed to complex mixtures of chemicals used and produced during the production process, and they often rotate through the plant where different jobs are running simultaneously. As one woman said: "We are pretty much being exposed to different materials every day . . . like one machine was ABS, another machine was nylon and they were ten feet away from each other" [16]. A government inspector's report identified air concentrations of hydrocarbons and halogenated hydrocarbons including methyl ethyl ketone, acetone, alcohol, and xylene in one workplace, adding that "fumes were strong and several workers developed symptoms of nausea, dizziness and headache" [19]. Another woman asked: "What's the synergistic effect of everything being mixed together?" [16].

Understanding the health effects of exposures on workers is not straightforward. For example, assessing the effects of vinyl chloride monomer is complicated by the fact that polyvinyl chloride resin includes not only vinyl chloride monomer but additives such as phthalate plasticizers, heavy-metal–based stabilizers, pigments, and processing aids, all chemicals with possible adverse health effects.

Several studies add weight to the hypothesis that exposure to complex mixtures of EDCs may have additive and/or synergistic effects. In a study conducted of women with breast cancer, researchers found an increased risk for leaner women exposed to a combination of endocrine-disrupting pesticides [49]. Adding to the significance of this finding is the fact that leaner post-menopausal women normally have a lower risk of breast cancer. A recent Spanish study found that women exposed to multiple environmental estrogens were at higher risk of giving birth to male babies with abnormal genital formations [50].

EPIDEMIOLOGIC EVIDENCE RELATED TO PLASTICS MANUFACTURING

Women who participated in the study spoke openly about their health concerns. "We had lots of cancers in our plant . . . 15 women and two men—all under 50 years old. And we also had one guy with breast cancer, which seemed odd. I never knew men could get breast cancer" [16]. Another woman told us: "I worked at the plastic plant for five years and then developed breast cancer when I was 32. There are six or seven breast cancers that we know of. They are all younger than 50" [16]. Several women spoke of miscarriages, infertility, and negative reproductive outcomes among their co-workers. The epidemiologic evidence suggests that such concerns and anecdotal accounts about breast cancer and reproductive abnormalities in plastics production are justified.

Breast Cancer

The case-control study by Brophy et al. that utilized descriptive data from the qualitative study [11, 16] found a more-than-doubling of breast cancer risk among women who had worked in automotive plastics manufacturing for 10 years and were assessed as having been highly exposed to EDCs and/or carcinogens (OR = 2.68; 95% CI 1.47-4.88). The risk for women who worked in food canning, where it is plausible that they were exposed to BPA from can linings, also more than doubled (OR = 2.35; 95% CI 1.00-5.53). Their risk for premenpausal breast cancer rose to more than five-fold (OR = 5.70; 95% CI 1.03-31.5) [15]. A 1998 study by Petralia et al. identified excess risk of breast cancer among women exposed to organic solvents and benzene (SIR = 1.8; 95% CI 1.4-2.3) in the plastics and rubber industries, which share many common exposures [51].

A 2008 study by Ji et al. of women working as plastics processing machine operators reported a doubling of breast cancer risk (OR = 2.0; 95% CI 0.9-4.3) [52]. The connection between breast cancer and employment in the plastics industry is strengthened by the finding of an excess risk of male breast cancer among workers in the rubber and plastics industries [26]. Male breast cancer is a rare event constituting only 1 percent of all diagnosed cases of breast cancer.

In 2010 Labreche et al. linked an excess risk of breast cancer with occupational exposures to synthetic textile fibres, acrylic fibres, and nylon fibres when exposure occurred before age 36 (OR = 7.69; 95% CI% CI 1.5-4.0) [53]. This supports the contention that women are vulnerable when breast tissue has not been fully differentiated. It is important to note that modern textiles consist mostly of polymer resins and additives, which are used extensively in plastics manufacturing. Similarly, a 2008 case-control study by Shaham et al. identified increased risk of breast cancer among women working in textiles and clothing industry (OR = 1.8; 95% CI 1.1-3.0) [54].

A 2011 study by Villeneuve et al. found an elevated risk of breast cancer for women employed in rubber and plastics products manufacturing (OR = 1.8; 95%

CI 0.9-3.5) [55]. The authors cite occupational exposure including night-shift work, solvents and EDCs as possible risk factors requiring further assessment.

Reproductive Health

In addition to the scientific literature that suggests a link between breast cancer and work in the plastics industry, there is considerable evidence that exposure to plastic substances affects reproduction. Workers also expressed concern about reproductive problems experienced in the workplace. One study participant observed that: "many men and women had reproductive problems like sterility . . . as well as lots of miscarriages, and some kids were born with developmental problems" [16].

A 1993 review by Baranski of the scientific literature on the adverse effects of occupational factors on reproduction cited many studies showing an increased risk of spontaneous abortions for women working in the plastics and rubber industries, and in women exposed to organic solvents [56]. The review found many studies showing infertility among women working in plastics and related industries, including synthetic rubber, caprolactam (a monomer used in the production of nylon), and styrene production. Other well-documented reproductive problems included delayed conception, premature delivery, and congenital malformations in the offspring of women rubber workers.

In 2009 an increased risk of infertility among women working in the plastics industry (RR = 1.23; 95% CI 1.01-1.48) was identified in a case-control study by Hougaard et al. [57].

CONTROLLING EXPOSURES AND FINDING ALTERNATIVES

Based on the available information regarding the toxicity of substances used in the plastics industry and our knowledge of workers' exposures, it is clear that more effective measures must be put in place.

Clearly, our current system of numerical limits does not protect plastics workers' health. As the interviews and review of government inspections reveal, women working in the plastics industry experienced serious symptoms and illnesses even though periodic air sampling results were often below the OELs. An early critique of OELs pointed out that only a minority of studies showed no adverse health effects below the established limits [58] and that the OELs were heavily influenced by industry to keep costs and liabilities down [59]. A more recent critique found clear scientific deficiencies in the determination of limits [60]. An international quantitative study noted the tendency for exposure limits to decrease over time, but expressed concern over the wide variation among limits for the same chemical in different countries [61]. Another limitation of OELs is their dependence on air sampling, which evaluates only how much of a chemical enters the body through inhalation, even though many chemicals are also absorbed through the skin, or inadvertently ingested. In addition, air samples may not be representative of usual conditions. Moreover, the OELs do not address possible health effects of exposure either to complex mixtures or to EDCs at low doses. The reliance on OELs needs to be completely re-evaluated in light of the growing understanding of the effects of EDCs on health. This may be particularly relevant to women workers whose health has been largely ignored in occupational health studies [62, 63] and in light of the growing evidence of reproductive and cancer risks from low-dose exposure to EDCs. Indeed, the most prudent protective measure would be to eliminate altogether occupational exposures to EDCs. In other words, we need a regulatory system that requires the elimination of worker exposures through substitution and engineering controls, particularly as they relate to EDCs, rather than one that relies on ineffective air monitoring and adherence to arbitrary exposure limits [64].

Unfortunately, free trade agreements and globalization have eroded worker protections. Companies, particularly those in such labor-intensive industries as plastics manufacturing, typically claim that protective safety measures are too costly and will lead to plant closures. International industry-wide standards would eliminate the companies' advantage of shutting down and moving to more poorly regulated jurisdictions.

Put simply, hazards must be controlled at the point of production. This can be achieved by substituting hazardous substances, enclosing hazardous processes, or re-engineering processes to eliminate the hazardous steps during production.

Several researchers make a convincing case for replacing EDCs in plastics production. Yang and colleagues, who found that most plastics products are hormonally active, argue that it is possible to substitute relatively inexpensive non-estrogenic monomers and additives [7]. A study of phthalates and their alternatives conducted by the Lowell Center for Sustainable Production also identified a large number of substances that could replace the use of phthalates as plasticizers, as well as plastics substitutes that use fewer and less harmful additives than those required for PVC products [65]. Importantly, the effectiveness of this approach would depend on a requirement to test substitute chemicals for endocrine-disrupting activity to ensure the safety of both plastic products and occupational environments. Where substitution is not achievable, employers should be required to introduce stringent process controls to prevent worker exposure.

CONCLUSION

This review raises major issues about health risks to women working in the plastics industry that have important implications for regulatory reform.

First, we found through worker interviews and a review of hygiene reports that plastics workers labor under very poor working conditions marked by inadequate to non-existent exposure controls and lax enforcement. What came through clearly is that enforcement is an unmitigated failure. By declining to issue orders to comply with occupational health regulations, inspectors, in effect, issue permits to endanger workers. Regrettably, there is good reason to believe that the examples provided represent the rule, rather than the exception [66]. The prevention of occupational disease requires a commitment to the principle of enforcement. To be effective, mechanisms must be put in place so that the cost of noncompliance is greater than the cost of compliance. In order to work, the system must be adequately resourced so that the likelihood of catching violators is high. Importantly, inspectors and hygienists must be empowered to focus on workers' health complaints and symptoms, their working conditions, and the state of exposure controls when issuing orders—and not primarily on exposure numbers and compliance with OELs, for the reasons cited above.

Second, through a review of the known health effects of substances used in the plastics industry we were able to ascertain that workers are chronically exposed to substances that are potential carcinogens and endocrine disruptors. This situation is aggravated by the fact that workers are exposed to complex mixtures of hazardous substances that may have additive and/or synergistic effects.

Third, we found through our review of the literature that workers carry a body burden of plastics-related contaminants that far exceeds those documented in the general public.

Fourth, existing epidemiologic and biological evidence indicates that women in the plastics industry are developing breast cancer and experiencing reproductive problems at elevated rates as a result of these workplace exposures.

Finally, it has been demonstrated that many plastics-related substances are EDCs with adverse effects at very low levels. The ability of EDCs to disrupt the endocrine system at low levels lends biological plausibility to the link between workplace exposures and increased risk of breast cancer and reproductive problems for women working in the plastics industry.

This situation cries out for swift regulatory review and action. If governments can take measures to protect the public from some of the EDCs in consumer products, surely we should expect similar action to protect plastics workers who are more severely and directly exposed. Required actions must include eliminating workers' exposure to hazardous chemicals used in the plastics industry. This can be accomplished most effectively by using substitutes for monomers and additives shown to be endocrine-disrupting chemicals. In addition, a comprehensive regulatory review of chemical hazards is needed. This involves adopting a new paradigm that goes beyond the traditional substance-by-substance review and toxicologic approaches. Attention must also be paid to assessing the health impact of complex mixtures. Furthermore, EDCs must be treated as a class of substances that disturb the normal function of the endocrine system, and therefore must be analyzed through methodologies and principles established in the field of endocrinology [67].

It is our contention that there is sufficient evidence that women working in the plastics industry face serious risks to their health as a result of preventable exposures. It is our hope that this review will generate increased discussion and action on the part of occupational health professionals, industry, and government, and—importantly—among workers and unions.

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Authors' note: Further descriptions of the qualitative study and research methods can be found in book chapters published in academic books: *"Consuming" Chemicals: Law, Science and Policy for Women's Health* [11] and *Rural Women's Health* [68].

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